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BUREAU OF MINES MINERALS YEARBOOK

Copper

UNITED STATES DEPARTMENT OF THE INTERIOR

The statistical data in this volume represents the most comprehensive, verified, domestic and international coverage for 1987 at the time the volume went to press. More recent information can be found in the monthly Copper Mineral Industry Surveys obtainable from Publications Distribution, Bureau of Mines, Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236.

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This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

Copper

By Janice L. W. Jolly and Daniel Edelstein[1]

As a result of escalating prices in the second half, 1987 proved to be a profitable year for almost all copper producers. Refined copper inventories reached the lowest levels since World War II as world copper consumption reached record-high levels. The shortage of spot copper was not ameliorated even though some new capacity from U.S. mines started operation by yearend. As a result, the domestic producer price of refined copper reached a record high $1.51 per pound at the end of December.

Table 1.—Salient copper statistics

(Metric tons unless otherwise specified)

	1983	1984	1985	1986	1987
United States:					
Ore produced thousand metric tons	177,930	171,814	162,210	169,238	202,632
Average yield of copper percent	0.51	0.58	0.62	0.62	0.58
Primary (new) copper produced:					
From domestic ores, as reported by:					
Mines	1,038,098	1,102,613	1,105,758	1,147,277	1,255,914
Value thousands	$1,751,476	$1,625,116	$1,632,483	$1,670,660	$2,284,156
Smelters	888,130	989,924	939,257	[1]908,087	[1]972,141
Percent of world total	11	12	11	10	11
Refineries	1,028,423	1,089,584	1,003,636	r [2]1,073,975	[2]1,146,107
From foreign ores, matte, etc., as reported by refineries	153,667	75,016	53,529	W	W
Total new refined, domestic and foreign	1,182,090	1,164,600	1,057,165	r1,073,975	1,146,107
Refined copper from scrap (new and old)	401,668	324,949	377,457	r405,944	414,738
Secondary copper recovered from old scrap only	449,478	460,695	503,407	r477,469	499,362
Exports:					
Refined	81,397	91,414	37,937	12,452	9,197
Unmanufactured[3]	239,190	317,167	435,069	442,441	387,245
Imports for consumption:					
Refined	459,568	444,699	377,725	501,984	469,159
Unmanufactured[3]	675,343	551,802	443,932	597,523	568,470
Stocks, Dec. 31: Total industry and COMEX:					
Refined	692,000	564,000	320,000	225,000	113,000
Blister and materials in solution	174,000	245,000	146,000	135,000	150,000
Consumption:					
Refined copper (reported)	1,803,931	2,122,732	1,976,038	r2,102,625	2,151,829
Apparent consumption, primary and old copper (old scrap only)	2,012,739	2,106,580	2,144,360	r2,135,976	2,217,431
Price: Weighted average, cathode, cents per pound, producers	76.53	66.85	66.97	66.05	82.50
World:					
Production:					
Mine thousand metric tons	r7,659	r7,999	8,080	p8,125	e8,475
Smelter do.	r8,120	r8,391	8,664	p8,715	e8,865
Refineries do.	r9,202	r9,116	9,375	p9,503	e9,647
Price: London, high-grade, average cents per pound	72.13	62.45	64.27	62.28	80.88

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Includes production from foreign ores and concentrates.

[2]Includes primary copper produced from foreign ores, matte, etc. to avoid disclosing company proprietary data.

[3]Includes copper content of alloy scrap.

U.S. apparent consumption of copper remained high, as did import reliance, which was estimated to be 26% in 1987. Refined copper imports continued to be high, but the ratio of domestic copper production to demand was increasing at yearend. U.S. mine production was recovering, and plans were being implemented to increase domestic production further. U.S. copper producers became increasingly competitive as they benefited from cost-reduction efforts of the past several years and from the weakened U.S. dollar. Restructuring of the industry continued with copper properties changing owners. Implementation of new technology leading to lower production costs also continued as one of the Nation's largest producers restarted its mine and processing plants, and another was well under way with construction of a new larger smelter.

Domestic Data Coverage.—Domestic production data for copper were developed by the Bureau of Mines from seven separate surveys of U.S. operations. Typical of these surveys is the mine production survey. Of 112 operations to which a survey request was sent in 1987, 90% responded, representing an estimated 99.9% of the recoverable copper content in the total mine production shown in tables 6, 8, 9, and 31. Production for the remaining 11 copper companies was estimated using data from other surveys.

Legislation and Government Programs.—Although current copper goals remained at 907,000 tons[3] of refined copper, only 20,000 tons was in the National Defense Stockpile. By yearend, Congress passed a measure contained in the fiscal year 1988 Defense Authorization Bill that would transfer management responsibilities for the stockpile to the U.S. Department of Defense.

Brass and bronze foundries were reportedly threatened by more stringent Occupational Safety and Health Administration (OSHA) standards for airborne transmission of lead. If forced to meet the 50-microgram-per-cubic-meter lead standard, many foundries reportedly would be forced to close.[3] An additional burden for the small foundry was the annual community right-to-know report that was required under Public Law 99-499, the Superfund Amendments and Reauthorization Act, 1986 (SARA). The requirement called for any facility that prepared a Material Safety Data Sheet under OSHA's Hazard Communication Standard to submit that sheet or a list of chemicals to the local emergency planning committee, to the State emergency response commission, and to the local fire department.

The Generalized System of Preferences (GSP) of the Trade Act of 1974 was amended through Presidential Proclamation 5758 of December 24, 1987, to suspend GSP treatment for Chilean imports, which included copper scrap. The suspension was the result of a determination that Chile had not taken steps to afford internationally recognized worker rights as defined under section 502 of the Trade Act.

In April, the Interstate Commerce Commission ruled that U.S. railroads had not complied until January 1981 with its 1979 order to reduce rail rates on nonferrous metals. The Commission ordered the railroads to reimburse shippers, with interest, for excessive charges levied between September 24, 1979, and December 31, 1980. Refunds for shippers of copper matte will amount to about 3% of the original charges, and shippers of copper or alloy copper scrap will receive refunds amounting to about 4.3%. An investigation was to continue to determine if other discriminations in rate structure existed.[4]

Two meetings were held in Geneva, Switzerland, under the auspices of the United Nations Conference on Trade and Development on the formation of an international producer-consumer forum for copper. A consensus developed among participating countries that there was sufficient basis to proceed toward the formation of such a forum and that a negotiating session would be convened in 1988 to develop functions and rules of procedure.

DOMESTIC PRODUCTION

Mine and Plant Labor.—Productivity, in terms of metric tons of copper produced and average hours worked at copper mines and mills, was 18.2 hours per ton of copper in 1987, down slightly from 17.7 hours per ton in 1986. The average number of U.S. copper mine and mill workers, including office workers, for 1987 was 11,924; 23,197,110 hours were worked. Although these statistics do not include mines producing byproduct copper, they do include staffing at mines that were closed or on care and maintenance status. U.S. Department of Labor statistics indicated that the average

number of employees at primary copper smelters and refineries was 5,600 workers in 1987, and 12,409,600 hours were worked. A total of 29.3 hours was spent per ton of primary copper processed through mine, mill, smelter, and refinery. This compared with 72.2 hours per ton in 1975.

Productivity continued to be an item of high interest among copper companies as a cost factor. In the first full year of operation, BP Minerals America expected its renovated Bingham Canyon operation to achieve a much higher level of labor productivity than that achieved previously. The work force, required to produce 185,000 tons of refined copper per year, was expected to be 1,800 people, or about one-fourth the size it was in 1980.

Copper Range Co. employed about 940 workers at the White Pine Mine; peak employment at the mine was 3,000 workers in 1978. Although technical and mandatory safety training played a vital role in the startup of the White Pine Mine, the need for extensive labor-management training, employee-ownership training, and cross-training for more than one job were equally important. More than $3 million in Federal and State funds helped provide the necessary training. Roughly two-thirds came from State-funded programs. The remainder came from the Federal Job Training Partnership Act, including title III, and the U.S. Reserve Fund for Dislocated Copper Workers. As a result of a better trained and involved work force, productivity increased sharply above that of 5 years prior when the mine was shut down.

Workers throughout the industry were paid various bonuses, reflecting the much improved copper market. The rise in Commodity Exchange Inc. (COMEX) copper prices triggered bonus payments, as negotiated in the 1986 labor contracts, and allowed most hourly copper workers to recoup some wages lost by salary and benefit-package concessions. About 4,100 copper workers in Arizona received contract-mandated bonuses totaling more than $10.4 million. The Magma Copper Co. workers reportedly recouped about one-half of the wage concessions made for 1987. The higher COMEX prices triggered Magma bonus payments during the third quarter that averaged $312 per employee and for the final quarter of the year that averaged about $2,600 per worker, or the equivalent of $5 per hour for each hour of paid time in the quarter. Magma employed 2,973 union-contract workers at its mine and smelter in San Manuel and 420 at its Pinto Valley Mine and concentrator at Miami. Magma was offering a starting wage of $10.50 per hour for new miners at the underground copper mine at San Manuel.

Inspiration Consolidated Copper Co. (ICC) issued bonuses to about 700 workers, averaging $2,346 per worker, or $4.50 per hour for each hour worked during the fourth quarter. Despite a lack of contractual obligation to do so, Phelps Dodge Corp. and BP Minerals America's Utah Copper Div. announced at yearend that all hourly employees would receive $1,000 each as a bonus.

Copper Range distributed $5,500 each to 800 union workers at the White Pine copper mine in the first payout under employee ownership. The distribution came under an employee stock ownership plan that allowed the enterprise to reopen in 1985 after a 3-year shutdown. The money and stock went to union workers who worked at least 870 hours in 1986. Copper Range stock, which was not traded publicly, was valued at $24.40 per share. According to the company, an average of 175 shares per worker were distributed, with a similar distribution to be made in each of the next 4 years. Copper Range also released about $1 million in incentive pay to the workers at the rate of 50 cents for each hour worked since January 1, 1986.

A total of 325 employees had been laid off at Tennessee Chemical Co. by yearend as a result of the company's decision to cease mining in Tennessee. The mining operation was completely shut down, as was the mill. Most of the employees at the iron roasters and on the maintenance staff were to remain until their work was completed. The mining company began its layoff procedures in late July for permanent closure of the mines.

Cost of Production.—The weighted-average, cash cost (including byproduct credits and taxes, but excluding depreciation) of producing refined copper in the United States was estimated to have decreased to about 53 cents per pound in 1987. When recovery of capital was included, the average production cost was 58 cents per pound.

ASARCO Incorporated estimated the cost to process 1 ton of material through crushing and concentrating at the Ray Mine to be $2.20 per ton. The recovery rate was 83.7% from heads of 0.88% copper and the concen-

trate grade was 26.7%. The cost to process Ray silicate ore through heap leaching, solvent extraction, and electrowinning (SX-EW) was estimated at $1.67 per ton.[6]

BP Minerals America claimed that its renovated Bingham Canyon, UT, property will easily be the lowest cost major copper producer in North America and one of the lowest cost producers in the world in terms of cash costs.[6] Inefficiencies and low productivity were addressed through better management and attention to operational improvement. Labor costs were reduced by about 35%, including the effects of work rule and practice changes, as a result of the 1986 labor contract settlement. Ore crushing, transportation, milling, and concentration systems were streamlined through the $400 million modernization project.

The modernization at Bingham Canyon used large-scale production to cut costs through less maintenance, fewer employees, and improved metal recoveries. Multiple haulage units were being replaced by large continuous transport systems, and many crushing, grinding, and flotation units were being replaced by fewer but larger pieces of equipment. About one-third of the project was directed at ore transport improvement through elimination of rail transport. In the pit, a large, single, mobile crusher replaced three fixed crushers, and a conveyor system was installed that extended 5 miles through a railway tunnel to a new concentrator. Three grinding lines, each consisting of one semiautogenous grinding mill and two ball mills, replaced more than 100 secondary crushing and grinding mills in the existing plants. A flotation circuit of fewer than 100 flotation cells, which included thirty-three 3,000-cubic-foot cells, replaced over 2,000 smaller cells in the existing plants. The final part of the system was a 13-mile slurry pipeline to carry tailings to the disposal pond. A second pipeline will return process water to the grinding plant, and a third will carry concentrates to the smelter.

Copper Range reported production costs at its White Pine, MI, mine to be about 60 cents per pound. High productivity was related more to the new employee-management relationship and cross-training than to implementation of new technology. Other than the modern refining plant, most equipment, mining methods, and smelting dated to the 1950's and 1960's. A conveyor-belt system was used for ore transport to the surface.

Solvent extraction and leaching played a significant part in reducing production costs for ICC. ICC, which built its SX-EW plant in the late 1960's and enlarged it in 1980, obtained its entire mine production from SX-EW in 1987. The company's 1987 costs were reported to be about 50 cents per pound. A new $15 million expansion of SX-EW plant capacity was expected to be completed in 1988.[7]

Magma announced in late 1987 that its copper-production cost goal was to reduce costs from 50 to 55 cents per pound to 45 cents per pound. Underground mining costs had been cut by about 9 cents per pound of copper through a reduction in the number of employees and a 20% reduction in wages and benefits. The implementation of a new underground mining plan was expected to further reduce costs by about 4 cents per pound. The company increased the cutoff grade of sulfide ore from 0.40% copper to 0.50% copper in its underground mine. The company planned to return to mining the 0.40% ore on an incremental basis. Mining the lower grade ore would add about 2 to 3 cents per pound to the average production costs. The 1986 cost had been unusually high owing to development work being done to expand future production. Costs for 1987 also were higher than what was anticipated in the future, since Magma's underground mine operated at reduced levels and was expected to do so until the availability of the new smelter in late 1988.

Magma was installing the flash furnace, which was expected to reduce smelting costs by 39% to about 7 cents per pound of copper. Since 1984, the addition of lower cost copper produced by the Pinto Valley Div. had reduced the weighted-average cost of production for the company. In addition, Magma anticipated electrowon copper could be produced at a cost of about 30 cents per pound from its new project at Pinto Valley with the addition of only 21 new employees. The cost of sulfuric acid used in copper-leaching processes at Magma's San Manuel SX-EW plant reportedly was reduced from $20 per ton to $9 per ton.[8] An annual cost savings of $498,000 was also realized through conversion of 20-inch cyclones to 26-inch cyclones; savings were derived from reducing the amount of power used and from the amount of scoop and cyclone maintenance that would be needed at the mill. In addition, the conversion paved the way for entry of a 6,000-ton-per-day, smelter-slag, grinding campaign. The cyclone modification allowed for easier transport of

slag in the grinding circuit from the rod mill to the ball mill. Magma's $267 million capital expansion program, aimed at an annual production goal in 1991 of about 272,000 tons of copper, was about 20% complete at yearend.

Since 1984, Phelps Dodge had invested about $275 million to reduce production costs. The investment included the acquisition of a two-thirds interest in Chino Mines Co. from Kennecott, which enabled Phelps Dodge to coordinate and rationalize costs for processing.[9] To date, costs had been reduced to about 55 cents per pound of copper from a high of more than 80 cents in 1981. Substantial capital programs had been completed or were planned, including various SX-EW programs and an in-pit crushing and conveying project at the Morenci Mine. Another $275 million was to be invested between 1988 and 1991 to further reduce costs. It was anticipated that as much as 40% of the company's production eventually would come from SX-EW production at its mines. Mining of the Tyrone ore body would be finished in the early 1990's, but SX-EW production from ore previously mined would continue for about 15 additional years. At this point, the corporation's costs, in 1987 dollars, were expected to be less than 50 cents per pound of copper.

Company Earnings and Ownership Changes.—Most major U.S. copper mining companies were profitable during the year, even though some had sold copper forward at prices lower than the escalating yearend COMEX spot prices. All companies had strengthened their financial positions by yearend and were producing copper at a profit for the first time in many years. Phelps Dodge announced a record-high income in 1987 of $207 million, almost double that of 1986.[10] Asarco reported a thirtyfold increase in earnings despite a significant loss from equity in foreign companies that were adversely affected by the devaluation of the U.S. dollar against the major foreign currencies in which the debts were denominated.[11]

Asarco's earnings improved as a result of lower operating costs in the United States, combined with higher metal prices. Costs for products and services were higher because of higher metal prices for raw materials. Asarco acquired the Ray Mine and associated smelter and SX-EW refinery from Kennecott in 1986 and the Eisenhower property from Anamax Mining Co. in 1987.

In a major restructuring during 1987, the British Petroleum Co., Plc transferred its 55% majority interest in the Standard Oil Co. to BP America (formerly BP North America Inc.), a wholly owned subsidiary.[12] On May 13, 1987, BP America gained control of the 45% minority interest of Standard Oil through a tender offer. The aggregate purchase price for the minority interest was about $7.8 billion. BP America then announced the formation of BP Minerals America, a new minerals company that combined the assets of Kennecott with those of Amselco Minerals Inc. From headquarters in Salt Lake City, UT, BP Minerals America was to manage British Petroleum's mining and mineral processing interests in the United States and select international locations. Higher copper prices, coupled with resumption of the copper operations at BP Minerals America's Bingham Canyon Mine near Salt Lake City, UT, were responsible for BP Minerals America's income improvement.

Cyprus Minerals Co. acquired two copper-producing properties during the year, the Pinos Altos, NM, underground mine and the in situ leach copper oxide mine at Casa Grande, AZ. According to the company's 1987 annual report, Cyprus also planned to complete acquisition of the Twin Buttes, AZ, mine in early 1988.[13]

The Bagdad copper mine operated at full capacity, and Sierrita's production was increased to take advantage of strong copper prices. Cyprus' participation in the higher copper prices was limited by forward sales of a large portion of second-half production.

Inspiration Resources Corp.'s (IRC) U.S. subsidiary, ICC, also was profitable, realizing for the full year an average COMEX-based price of 71 cents per pound.[14] Every one-cent-per-pound increase in the price of copper translated into between $1.5 and $2.0 million in annual pretax income for IRC, depending upon factors such as the continued impact of price participation bonuses that were paid to mine employees under the current labor contracts.

Magma's losses in the final quarter of 1987 included a $25 million reserve to close out forward-sales contracts covering about 47 million pounds of copper for the first quarter of 1988.[15] Instead of delivering copper, Magma paid the difference between the contract and market prices. The company bought out the forward contract in order to sell more copper at full market price and to make earnings more predictable.

On March 10, 1987, Newmont Mining Corp. declared as a dividend to its share-

holders 80% of its equity in Magma, then a wholly owned subsidiary. Newmont retained 15% of Magma's common stock and 5% was placed in an incentive plan for Magma management. A services agreement between Magma and Newmont allowed Newmont to provide Magma with certain exploration, marketing, electronic data processing, and other administrative services until December 31, 1989. As part of the spinoff arrangement, a $225 million financing agreement was organized with several banks, which set tight operating and spending targets for Magma's capital expenditure program. Newmont guaranteed the first $75 million in term loans. The capital expenditure program was subject to certain spending covenants and a completion deadline of yearend 1989.

Montana Resources Inc. (MRI) made its last payment to the Montana State Board of Investments at yearend.[18] The board arranged for a $12 million line of credit for MRI, which borrowed a total of $7.1 million from the fund. The total economic impact of the mine in the first year of operation upon the Butte, MT, community was reportedly more than $34 million, including $16.1 million in salaries and other worker compensations, $4 million in property and severance taxes, and $14.5 million in direct purchases throughout the State. MRI based its operational budget for the Continental Mine, Montana, on copper selling at 65 cents per pound and molybdenum at $2 per pound; both of these prices were exceeded during the year.[19]

Mine Production and Reserves.—Copper was mined in 11 States during 1987, with Arizona yielding 61% of the total, followed by New Mexico and Utah. There were 52 copper-producing mines, down from a total of 87 mines in 1986. Of these, 23 were producing copper mines and 29 were mines from which copper was produced as a by-product or coproduct of gold, lead, silver, or zinc. Total U.S. operating mine capacity, in terms of recoverable copper per year, was estimated to be 1.52 million tons. The Bingham Canyon open pit was reactivated in late 1987, and increased leaching and SX-EW capacity was added at the Morenci, Tyrone, and San Manuel Mines. Tennessee Chemical's copper operations at Copperhill, TN, closed at midyear. Capacity utilization at operating mines was 83%.

Asarco acquired the balance of the Eisenhower general partnership interest of the Anamax Mining Co. in April 1987 for $1 million. Asarco's combined Mission Complex comprised the Mission, Eisenhower, Pima, and San Xavier Mines, the ores from which were processed through the Mission mill. Average mill recovery rates for 1987 were as follows:

Mine	Quantity milled (metric tons)	Recovery rate (percent)	Copper (metric tons)	Silver (thousand troy ounces)
Coeur	141,000	97.90	998	2,449
Galena	182,000	97.00	907	3,288
Mission Complex	9,004,718	88.60	53,161	810
Ray	8,807,859	84.20	97,704	378
Silver Bell	--	--	5,806	--
Troy	2,852,100	87.60	16,783	4,297

Source: ASARCO Incorporated 1987 Annual Report.

The reserve base for the Ray Mine, which consisted of 630 million tons of ore averaging 0.71% copper, was defined by a 0.35% cutoff and included 65 million tons of silicate ore averaging 0.89% copper. However, the current 13-year mine plan was based on a 0.52% copper cutoff. Metal production for 1987 shown above for Ray included electrowon recovery of 29,000 tons and precipitate production of 2,360 tons. Only copper precipitates were produced at Silver Bell.

Leaching at the Ray Mine was carried out on four active, run-of-mine, sulfide, waste dumps and several silicate ore heaps. Ore was precrushed for the silicate leach system and then treated with dilute sulfuric acid solutions. Cost of processing material through heap leaching was estimated to be $1.67 per ton of ore. Silicate ore grade for the silicate ore heap-leaching process was 1.14% copper, with 0.87% of the ore readily soluble. About 122 pounds of acid was consumed per ton of ore leached. Primary crushing was done at the mine, followed by

secondary and tertiary crushing at nearby Hayden. Concentrate grade from milled ore at Ray was 26.7% copper. About 25 tons was milled per worker-hour. Tailings deposits covered 1,405 acres.[18]

The following is a summary of Asarco's properties, ore reserves, and percentage ownership:

Mine	ASARCO (percent owned)	Ore reserves (thousand metric tons)	Percent of reserves			Silver (troy ounce per ton of ore reserves)
			Copper	Lead	Zinc	
Coeur	50.00	450	0.77	--	--	16.64
Galena	37.50	1,087	.59	10.04	0.11	16.09
Mission Complex	100.00	333,360	.64	--	--	.12
Quiruvilca	80.00	5,332	.99	1.26	3.57	5.96
Ray	100.00	614,373	.70	--	--	--
Silver Bell	100.00	19,011	.68	--	--	.07
Troy	75.00	34,451	.75	--	--	1.52
West Fork	100.00	9,796	.04	7.07	1.94	.30

Source: ASARCO Incorporated 1987 Annual Report.

BP Minerals America was building its competitive position in copper and other precious metals and minerals markets. The $400 million modernization of the Bingham Canyon Mine was nearing completion, with production costs reportedly lower than expected. Operating improvements at all plants had raised labor productivity to twice that of 1980. According to the company, when byproduct credits for gold, silver and molybdenum were translated into equivalent copper grade, the equivalent "grade" at the Utah mine exceeded the average grade of the seven largest mines in the United States other than Bingham, and the stripping ratio was as low as that of any of these mines. In addition to the high equivalent "grade" and low-stripping ratio, the Utah mine had large ore reserves that could support an operating life of about 30 years under current mine plans. If metal prices improve, additional years could be added. The cutoff grade was raised to 0.45% copper, which lowered the reserves, but raised the average mill-head grade and lowered unit costs. Revised mining plans also reduced the stripping ratio. Production expectations for the Bingham Canyon Pit were 173,000 tons of copper, 300,000 troy ounces of gold, 2.3 million troy ounces of silver, and 12 million pounds of molybdenum per year. Phase-in of the new facilities was scheduled to begin in the second quarter of 1988, with full operation to follow by October.

BP Minerals America listed Bingham Canyon copper reserves as 7.3 million tons of copper in 1986 and 7.1 million tons of copper in 1987, including proven and probable, contained in 891 million tons of ore in 1986 and in 899 million tons of ore in 1987.[19] As a result of the divestiture of the Ray and Chino Mines in 1986, all of the company's remaining reserves were at Bingham Canyon.

At midyear, BP Minerals America announced its intention to reapply for a permit to mine its Ladysmith, WI, copper-gold ore deposit, a relatively small deposit near the Flambeau River. Kennecott had withdrawn its 1975 environmental impact report and request to open the mine owing to the depressed metals market. The tabular-shaped, nearly vertical, quartz-sulfide vein averaged about 50 feet in width and was about 2,400 feet long. The upper 200 feet of the vein, which had been secondarily enriched, was to be mined in an open pit operation. The overburden, consisting of sandstone and glacial gravels, could be removed easily using bulldozers and used for road construction, plantsite preparation, and dressing of the slopes of the waste storage areas. The mine, which would employ about 35 people, would produce about 13,600 tons of ore per day and would cost between $15 and $20 million to develop.

The Ladysmith deposit contained 4 to 5 million tons of ore with 4% copper and traces of gold and silver. Mining by open pit methods was to last about 5 years; however, underground mining could follow if it proves economically viable for recovery of material from the lower 600 feet of the ore body.

Butte's old underground mines were purchased by Montana Mining Properties (MMP) from Washington Corp. of Missoula in April. In August, MMP, a group of Australian and European investors, incor-

porated several new mining companies with claims on Butte Hill. They included Butte Precious Metals, the Central Butte Mining Co., Mountain Con Mining Co., North Butte Mining Co., West Butte Metals Inc., the Tzarina and Travona Mining Co., and the Blue Bird Mining Co., according to county court records.[20] A new firm, Butte Mining Plc, with stock listed on the London Stock Exchange, was announced in October.

Butte Mining announced intentions of investing up to $100 million for the purpose of resuming surface and underground mining on a portion of the Butte Hill and construction of a new mill in the city. The mouth of the mile-long Alice-Lexington Tunnel was rehabilitated so that easy access could be made to Butte's underground mines. The tunnel, which ended under the Alice Pit, was a key underground access connecting the Lexington Mine (at the 400-foot level), the Missoula Mine, and the Syndicate Pit. Butte Mining was to develop only 2 of the 14 different blocks of claims that had been purchased by MMP, the Tazarena and Rainbow blocks, which were near the Lexington and Travona Mines. The minesites were last active in the 1950's. After positive recommendations from international mining consultants who did research on Anaconda Minerals Co.'s old records, Butte Mining decided not only to resume mining in Rainbow and Tazarena, but to conduct further exploration for more reserves. The Kelley Mine offices were serving as headquarters for both MMP, which will serve as a property management company engaged in trying to bring the Butte Hill mines back into production, and Butte Mining, which will also have offices in London, United Kingdom.

Cyprus continued to diversify into new markets and to acquire new copper-producing mines. In 1987, Cyprus acquired two more copper properties in Arizona and New Mexico. In late 1987, Cyprus began operations at Pinos Altos, an underground copper mine in New Mexico, which was acquired from Boliden Minerals Inc. The mine was situated on a combination of unpatented mining claims and fee properties and was held by Cyprus under a long-term lease. Cyprus expected to produce 3 to 5 million pounds of low-cost copper and some silver at Pinos Altos in 1988 and was evaluating the gold potential of the mine. The company also formed a joint venture with St. Cloud Mining Co. to mine silica flux in New Mexico for sale to a local smelter.

Cyprus acquired the Casa Grande (formerly Lakeshore) underground copper mine in western Arizona from Noranda Inc. in June. The mine was on Indian reservation lands leased from the Tohono O'odham Nation. Cyprus mined the oxide ore by in situ leaching and produced copper cathode from an SX-EW plant at the mine. During 1988, Cyprus planned to produce about 45,000 tons of leached copper at Casa Grande, some of which would be derived from its other mines. Cyprus planned to roast some of the copper concentrates from its Sierrita Mine at an on-site roaster at Casa Grande. The roaster could process 136,000 tons of concentrates per year. By using the low-cost, roast-leach operations, Cyprus expected to reduce Sierrita's concentrate-treatment costs. Work also was to continue on the development of in situ recovery of additional leachable copper from large deposits on the Casa Grande property.[21]

At yearend, Cyprus was negotiating to acquire the Twin Buttes, AZ, open pit copper mine near Sierrita. Sulfide ore from this mine was to be shipped to Sierrita for processing. The Twin Buttes SX-EW plant was to be refurbished and reactivated in 1988. Cyprus expected to produce about 11,000 tons of copper from the Twin Buttes Mine in 1988.

Cyprus mined copper sulfides, molybdenite, and a small amount of oxide ore for leaching at the Bagdad Mine, Arizona. The operation consisted of an open pit, a 50,000-ton-per-day sulfide concentrator, and an oxide heap leach system with an SX-EW plant. The mine, mill, and plant operated at full capacity in 1987, producing about 83,000 tons of copper, according to the company annual report.[22]

Cyprus also owned and operated the Sierrita copper and molybdenum mine, which consisted of an open pit, an 84,000-ton-per-day sulfide ore concentrator, a molybdenum plant and roaster, and related mining equipment. Copper concentrates were shipped to domestic smelters for processing. Sierrita also used an oxide ore heap-leaching system with a SX-EW plant to produce copper cathode. Sierrita operated at near capacity during the year.

At yearend, Cyprus' proven reserves at the Sierrita Mine totaled 295.5 million tons of ore, containing an average grade of 0.30% copper and 0.037% molybdenum. The company's proven reserves at Bagdad totaled 387 million tons of ore, averaging

0.45% copper at yearend 1987. Cyprus' newly acquired Pinos Altos Mine had proven reserves of 830,000 tons of ore, containing an average of 4.91% copper. The Casa Grande (Lakeshore) Mine had proven reserves totaling 14 million tons of ore, containing an average of 0.80% copper, and the Twin Buttes Mine had proven reserves of 34 million tons of sulfide ore, containing an average of 0.92% copper and 9.6 million tons of oxide ore, containing an average of 0.73% copper.[53]

ICC reported mining 30 million tons of ore, containing 0.589% copper. During 1987, ICC increased its proven reserves of copper through successful drilling. Reserves at active surface mines and properties at ICC were given as 151 million tons containing 0.60% copper. This compared with 111.3 million tons with 0.57% copper reported in 1986. Reserves (reserve base) at inactive mines totaled 99.6 million tons of 0.51% copper and included sulfide reserves at the open pit. ICC's inactive underground mine was given as 18.2 million tons of 1.84% copper.[54]

Magma and Cyprus agreed in principle to form a joint venture under which Cyprus would explore for gold on Magma's San Manuel, AZ, property. Cyprus would have the right to earn a 50% stake in the gold property by carrying out exploration activities. Cyprus also would become operator of the gold property when developed.

Magma's San Manuel concentrator had a rated capacity of 56,000 tons of ore per day. The mill feed was reportedly averaging 0.65% copper and 0.026% molybdenum. Concentrates containing 29.5% copper and 1.00% molybdenum were produced. Magma started test production from its mechanized load-haul-dump system during the last week of June. However, technical problems encountered in the test runs made it unlikely that the system would be cost-effective. Therefore, it would not be used to replace the existing manual system in the mine as planned.

A formal test program began for recovering copper using in situ leaching in an area overlying the mined-out portion of the mine. In addition, Magma was actively mining in an open pit that was developed in the oxide ore contained within an active subsidence zone over the underground mined-out area. Magma used a prepared, 86-acre, dump-leach site with an impermeable liner for leaching the mined oxide ore.

Construction of a $19.6 million SX-EW project at Pinto Valley started during the year; the project was to be fully operational in 1988. About 7,000 tons of low-cost copper cathode per year was to be recovered from the 220-acre No. 2 tailings pile at the Pinto Valley Mine, which contained 32 million tons of material grading 0.33% copper. Pinto Valley will reclaim the copper by hydraulic mining, followed by processing through the expanded Miami SX-EW Unit.

Early drilling campaigns by Magma identified an oxide ore reserve in the open pit, dump-leach area of about 51 million tons of 0.41% copper ore and, in the in situ area, an oxide reserve of about 97 million tons containing 0.36% copper.[55] In 1987, however, the company reported that exploration drilling had resulted in an increase of oxide reserves by more than 64 million tons. Previous reports had put San Manuel sulfide reserves at 270 million tons of 0.69% copper, which included 94 million tons contained in the shaft pillar.[56] A reevaluation of the mine plan at Pinto Valley caused the company to increase minable sulfide reserves by 174 million tons.[57] Previous reports had put Pinto Valley sulfide reserves at 323 million tons of 0.40% copper ore. Favorable drilling results were also obtained in an area known as Cactus Claims.[58]

MRI marked its first full year of operation in July 1987. Silver production was reported as just about covering the company's monthly diesel fuel costs for the trucks that haul ore from the pit to the concentrator. MRI was shipping copper concentrates to Japan and molybdenum concentrates to the United Kingdom.[59]

Phelps Dodge was the largest domestic producer. According to the company's 1987 annual report, its mines and electrowinning facilities produced a record high 498,680 tons of copper in 1987, including a share belonging to Japanese partners Sumitomo Metal Mining Corp. and Mitsubishi Corp., which owned part of Chino and Morenci production. Of the total, about 42,000 tons was electrowon cathode from the Morenci and Tyrone Mines. A substantial tonnage of concentrates, which was in excess of the company's smelting capacity, was either

sold or toll refined. In addition to the electrowon copper, the following was recovered at each mine:

Mine	Ore mined (thousand metric tons)	Grade (percent of copper)	Precipitates recovered (metric tons)
Bisbee	--	--	9,900
Chino	9,427	0.81	15,694
Morenci	20,647	.82	11,430
Tyrone	15,584	.88	7,600

Source: Phelps Dodge Corp. 1987 Annual Report.

Ore reserves and reserve base in the United States were reported by Phelps Dodge as follows, including partner shares:

Mine	Ore reserves (thousand metric tons)	Average grade (percent)
Ajo	189,800	0.51
Chino	218,000	.71
Copper Basin	159,600	.55
Dos Pobres	210,100	.69
Lonestone	100,060	.41
Morenci	670,000	.76
Tyrone	97,200	.79
West Ca/NW Extension	219,000	.69

Source: Phelps Dodge Corp. 1987 Annual Report.

Sumitomo owned 15% of Morenci and adjacent Western Copper reserves. Mitsubishi owned 33-1/3% of the Chino Mine reserves. Ajo, Dos Pobres, and Western Copper were yet to be developed, hence, were considered as reserve-base copper rather than reserves. The Lone Star property near Safford, AZ, which was acquired from Kennecott in 1986, was also in this category. A potentially significant copper deposit was delineated by diamond drilling near Bisbee, AZ. At yearend, preliminary estimates had indicated about 154 million tons averaging 0.50% copper. Secondary chalcocite occurred near the surface and was thought to be amenable to heap-leaching and SX-EW recovery. Phelps Dodge was to continue sampling and feasibility studies through 1988.

In April, Sharon Steel Corp. filed for bankruptcy under chapter 11 of the Federal Bankruptcy Act seeking protection from its creditors. Although Sharon Steel's Continental Mine in New Mexico was shut in 1982, Texas-New Mexico Power Co. alleged in a lawsuit that Sharon Steel's termination of an electric service contract was not effective until June 30, 1985. The mine has been kept on care and maintenance by a crew of 10 where about 500 mining and milling personnel were once employed. Substantial reserves reportedly remain.[90]

The State of Tennessee purchased the 16.4-acre Burra Burra Mine site, the oldest in the Copper Basin, to help preserve the historic industrial complex. This was to be Tennessee's first State-owned historical industrial site, which includes the sealed entrance to the copper mine and 13 buildings that date from 1900 to 1922. Mining was discontinued here in 1958. The site was placed on the National Register of Historic Places in 1983.

After 144 years of commercial copper mining in Copper Basin, TN, Tennessee Chemical's mines were closed in early August. About 250 employees had already left through attrition and early retirement programs following the closing announcement 30 months prior to shutdown. The company will continue to manufacture sulfuric acid and copper chemicals, retaining 325 jobs. Eventually, a total of 650 workers will have been laid off.

Mine Environmental Issues.—The Environmental Protection Agency (EPA) reportedly spent more than $20 million since 1983, when it began negotiating with the Atlantic Richfield Co. for testing and remedial action of land and water damages that resulted from decades of mining, smelting, and other industrial processes in Montana. Of the total, about $17.1 million was spent for various public and private contracts at five sites. Most of that, $9.2 million, was spent on the Silver Bow Creek-Butte site for testing and removal of contaminated soils in Walkerville and for monitoring flooding in the Berkeley Pit and underground workings. The agency also spent $4.1 million at Anaconda, which includes Mill Creek, Smelter Hill, the old reduction works, the Arbiter plant, and the tailings ponds north of Smelter Hill. An additional $2.7 million was spent at Milltown Reservoir, which was contaminated with arsenic and other heavy metals carried downstream from the Butte mining district and the Anaconda smelter. An additional $1.3 million was spent on studies along the Clark Fork River. EPA and Montana agencies identified 77 potential contamination problems within the Clark Fork Basin, which reportedly was the largest Superfund site in the country.[91]

Projects involving concrete capping of old mine shafts and hauling away tailings were also completed or under way during the year. Three shafts, east of North Main in

the Mountain Consolidated complex of Montana, were capped, and tons of tailings were hauled away. Similar capping and hauling at the West Grey Rock (at the end of Center Street) and the Belle of Butte (east of the Alice Pit and the Steward Mine) were being carried out as part of a reclamation and mine-shaft capping project on Butte Hill.[22]

Smelter Production.—Even though several smelters closed during the year, primary and scrap smelter production increased in 1987 compared with that of 1986. Nine primary smelters with a combined capacity of 1.2 million tons operated most of the year. In addition, five secondary smelters with a combined capacity of 282,000 tons operated. Two primary smelters with a combined capacity of 148,000 tons per year closed permanently during the year; one was a reverberatory smelter in Arizona and the other was an electric smelter in Tennessee. One new flash smelter was under construction in Arizona, and one large smelter reopened in Utah.

U.S. smelter capacity, by process category, was as follows:

Process	Smelter capacity (metric tons, copper in blister)	
	1975	1987
Outokumpu flash	--	160,000
Inco flash	--	288,000
Noranda modified	--	210,000
Electric	336,000	112,000
Reverberatory (primary)	1,444,500	386,000
Reverberatory (secondary)	208,400	281,000
Total	1,988,900	1,437,600

The significant shift in type and amount of smelter capacity was indicative of the rapid change since 1975 toward energy-efficient capacity with greater sulfur dioxide capture. The White Pine smelter was the only U.S. smelter operating without a sulfuric acid plant, which was not practical owing to the low sulfur content of its ores.

Asarco produced blister copper from two domestic smelters, one at El Paso, TX, and another in Hayden, AZ. The company's Hayden-Ray smelter, with a 100,000-ton-per-year capacity, was acquired from Kennecott late in 1986 but remained closed during 1987. Asarco's smelter production was down slightly from that of 1986. The annual capacities for the Hayden flash smelter and for El Paso were estimated to be 168,600 tons and 104,000 tons, respectively.

Pyrite from the Ropes Gold Mine at Ishpeming, MI, was tested for use at Copper Range's smelter at White Pine, MI. The pyrite was to be used along with that imported from Canada, which was received by barge across Lake Superior. The pyritic ore, used as a smelter flux, was shipped by truck from the Ropes Mine and was less expensive. Copper Range also received coal for its company-owned electric plant through the Ontonagon pier on Lake Superior.

Cyprus planned to process a small portion of its concentrate production at its newly purchased, 136,000-ton-per-year roasting plant at Casa Grande, AZ. In addition, Cyprus had toll smelting and refining and concentrates sales agreements with Magma and three other domestic and foreign custom smelters. These contracts were expected to cover about 75% of estimated 1989 production and 45% of estimated production between 1990 and 1997. A 1986 agreement with Magma, which covered a minimum of 300,000 tons or about 50% of Cyprus concentrates production, was to commence in 1988. The agreement was to terminate in 1997 and was contingent upon the availability of Magma's new smelter capacity in the second quarter of 1988.

ICC continued to operate its smelter at full capacity, treating purchased and tolled concentrates. ICC had arranged for enough concentrates (345,000 tons of concentrates per year) to operate at capacity through 1989. ICC's smelter and acid plant produced 92% of the sulfuric acid required by the leaching operations. ICC completed several smelter improvements, including the installation of a new anode-casting facility and two gas coolers that permitted it to reduce costs and increase smelter efficiency.

According to its annual report, Phelps Dodge produced only 238,400 tons of blister copper at its U.S. smelters in 1987, down considerably from 325,200 tons reported in 1984. Phelps Dodge had smelted and refined most of its own mine production, but owing to smelter capacity cutbacks of recent years was selling the excess concentrates, or having them toll smelted both domestically and abroad. The company's Douglas smelter in Arizona was closed permanently in January 1987, as a result of environmental noncompliance.

An Outokumpu flash-smelting furnace was under construction at Magma's San Manuel smelter in Arizona. The design capacity was to be 2,722 tons of concentrates per day, capable of producing about 272,000

tons of copper per year, based on predicted feed grade.[53] It will be the world's largest furnace of its type. Startup was planned for August 1988. Outokumpu Engineering Inc. was awarded the contract for the smelter modernization program, which included concentrate drying, a flash furnace, furnace feeding systems, flue-dust handling, and gas cleaning and handling systems. Davy McKee Corp. of California was the general contractor for the project. Other major contracts were awarded to Lurgi Inc. for converter gas handling, Monsanto Chemical Corp. for the acid plant, and Liquid Air Corp. for the oxygen plant. The gases from the new flash furnace were expected to run about 31% sulfur dioxide. Only four converters were required to process the matte, which would average 63% copper. Four new jet scrubbers were to replace the current gas-handling system from the converter. Both the slurry produced by the scrubbers and the dust captured by the electrostatic precipitators contain copper and were to be recycled. Slag cleaning for the furnace was to be done by flotation.

Smelter Environmental Issues.—Minproc Ltd. of Australia, which was a substantial shareholder of Artech Recovery Systems Inc., was preparing the final feasibility study for the recovery of metals from flue dust at the Anaconda Copper Reduction Works in Anaconda, MT. The site contained an estimated 327,000 tons of flue dust. Artech Recovery and CSS Management Corp. formed a joint venture, called Artech Ventures, to recover bismuth, copper, gold, lead, mercury, silver, and zinc from the arsenic-bearing flue dust. A hydrometallurgical process for economic recovery of the metals was being tested. Earlier testing indicated that arsenic in the treated flue dust would be chemically bound in insoluble precipitate and would not be hazardous. The processing method, called the Cashman process, was developed following 5 years of joint research and development with the Bureau of Mines. Processing operations were planned to begin in 1988 with 97 tons of flue dust per day, expanding to 363 tons per day. About 20 to 35 people would be employed during construction and operation of the plant.[54]

However, at yearend, Artech was waiting for EPA to determine if the encapsulated arsenic could be stored on Smelter Hill and whether the now closed Arbiter SX-EW plant could be used for processing the material. U.S. Department of Transportation regulations also would apply to the project if moving the hazardous dust across Highway 1 to the Arbiter plant was determined to constitute public transportation. A Montana Water Quality Bureau discharge permit would also be required.

EPA ordered the eight remaining families of Mill Creek, MT, to leave the 160-acre community owing to health problems that ostensibly were related to heavy-metals contamination from the now closed Anaconda smelter. Permanent relocation was ordered to address the imminent health risks from high levels of arsenic, cadmium, and lead in the area. The residents filed a lawsuit against Anaconda seeking damages for health problems associated with living near the smelter. Under a proposed EPA-Anaconda consent agreement, Anaconda had 1 year to buy the remaining eight homes. EPA began investigating Mill Creek after urine samples taken in 1985 revealed elevated arsenic levels in several young children. Anaconda had since purchased 24 lots and had moved 19 families.[55]

Asarco received notices from EPA concerning releases or threatened releases of hazardous substances, pollutants, or other contaminants under the 1980 Superfund law regarding the former Houston plantsite of Federated Metals Corp., a wholly owned subsidiary. Federated Houston's scrap-processing plant in Texas was closed permanently in 1984. In January 1987, this plant was listed on the Texas State Superfund Registry.

A settlement reached with the Arizona Department of Health Services and the EPA allowed Magma to continue operating its San Manuel reverberatory smelter until the new flash furnace was completed. The consent decree, completed February 23, established a November 1, 1988 deadline for completion of its smelter project, which will fully comply with Federal and State air-quality standards. Interim air-quality standards that the reverberatory smelter must meet were established, along with penalties, if these standards are violated. A past air-quality violation penalty of $600,000 was to be paid by Magma, in addition to posting a $20 million letter of credit guaranteeing compliance with the November 1988 deadline. The Federal Clean Air Act had set January 1, 1988, as the deadline for full compliance with air-quality standards.

Refinery Production.—Refinery production was considerably higher than that of

1986 owing to the reactivation of some capacity, as well as to the startup of expanded or new electrowinning capacity. During 1987, 26 refineries operated, including 10 electrowinning plants, 9 primary and secondary electrolytic plants, and 7 secondary fire-refining facilities; no primary fire refining was reported during the year. Annual U.S. refinery capacity was estimated to be 1,980,000 tons of primary and secondary refined copper. Primary refinery capacity consisted of 1,425,000 tons of electrolytic cathode and 182,000 tons of electrowon cathode.

Asarco reported capacity at its Amarillo, TX, refinery as 414,000 tons and at its recently acquired Ray SX-EW plant in Arizona as 36,000 tons. Asarco's refined copper production was 53% from purchased material, 13% from tolled material for others, and only 34% from the company's own mines. Copper cathodes were produced at the rate of 82 tons per day from the company's Ray SX-EW plant; about 21 tons per day was from sulfide dump leaching, and 61 tons per day was from silicate leaching.

BP Minerals America restarted its refinery in Utah at the end of July. However, full capacity was not expected to be reached until mid-1988, following completion of the mining and milling renovations.

Copper Range had two anode furnaces, one of which was completely rebuilt. From a holding furnace, fire-refined copper was fed through a Hazellett Inc. continuous-casting anode machine. The anode was cut into shape for the refinery from the hot metal sheet, providing a very smooth, uniform anode. Cathode produced by the electrolytic refinery was very pure and was used mainly for magnet wire, according to company officials. Cathode was shipped by truck to Ontonagan from where it went by rail to market. Copper Range was leasing the modern refinery from Echo Bay Mining Ltd. Although there was a specialty casting shop on the premises for making custom cake, rod, and other forms, including high silver-copper alloy, this part of the plant was not being used. It was anticipated that a nickel sulfate line would be put back into operation in the near future. The refinery, which used the Australian Isa process with stainless steel starter sheets, was constructed by Copper Range (Louisiana Land and Exploration Co.) during 1982 and was used for processing scrap during the mine closure from 1982 to 1986.

Near the end of August, Cox Creek Refining Co. of Baltimore, MD, started limited production of copper rod for customer testing and qualification, but full production was not scheduled to begin until 1988. The associated refinery remained idle. Production at the rod mill was from toll cathode and copper scrap, both alloyed and unalloyed. Mitsubishi Metal America joined the venture, providing a supply of raw material for refining and rod production. Halstead Industries Inc. of Zelienople, PA, also joined Mitsubishi and Southwire Co., Georgia, as investors in Cox Creek. Each of these companies owned 20% of Cox Creek, which was purchased from Kennecott. Securing copper supplies in the tight yearend market was a major hurdle for the company before it could begin large-scale production. The Baltimore refinery's capacity was put at about 180,000 tons per year. Kennecott dismantled some tankhouse capacity prior to closing. The original annual capacity had been 254,000 tons.

In 1987, ICC increased proven reserves of low-cost leachable ore at its Arizona-based operations by more than 40% from 1986 levels. It also expected to reduce cash costs of production by about 5 cents per pound after additional SX-EW production of about 11,500 tons starts in the fourth quarter of 1988. Exploratory drilling had proven the availability of sufficient reserves to continue all-leach production at ICC for more than 12 years at current operating rates. In addition, a modernization of ICC's tankhouse was under way and scheduled for completion in 1988. In 1987, the company produced 48,000 tons of copper from leach extraction methods. In 1987, ICC's tankhouse and rod mill produced a record high 78,000 tons of cathode and 120,000 tons of copper rod, respectively.[28]

As part of the tailings reprocessing project at Magma's Pinto Valley Div., capacity at the Miami Unit SX-EW operation was to be doubled from about 15 tons of copper per day to 30 tons per day. In addition, copper starter sheets were to be eliminated at the Pinto Valley tankhouse; instead, a conversion to stainless steel blanks was being made, as was already the case at the company's San Manuel SX-EW plant.

The 100% expansion program of Magma's San Manuel SX-EW plant was about 65% complete at yearend. The new plant was to recover copper from solutions generated by the new in situ, oxide-ore-leaching project and was being built adjacent to the first SX-EW plant, brought on-line last year. The

first plant was recovering copper from heap-leaching oxide ore that was being mined by open pit methods from the oxide ore body over a mined-out portion of the sulfide ore zone. Owing to delays occasioned by the need to complete underground mining of the underlying sulfide ore, the scheduled startup for production by the in situ plant may be as late as 1989; eventually, the new plant will double electrowon copper production to 45,500 tons per year. Magma found that the Australian Isa process was a complete success and enabled production of high-quality copper. In its first year of operation, the existing 25,000-ton-per-year plant was producing a little more than its rated capacity. Although production costs for heap leaching were listed by Magma as less than 50 cents per pound, in situ production costs were expected to be substantially lower. The in situ site was at the eastern edge of San Manuel's open pit oxide mine, in the north central portion of the subsidence zone. Injected fluids were to percolate down through 1,000 feet of ore before reaching the collection point at the 2,375-foot level underground. The ore block contained about 161 million tons of recoverable copper and was expected to have a 10-year life.

A third expansion at the Tyrone, NM, SX-EW plant, which was operated by Burro Chief Co., was to increase the plant's annual capacity to 50,000 tons and was nearing completion. A new 41,000-ton-per-year facility was under construction at Chino Mines, with initial production scheduled for the fall of 1988. The 45,000-ton-per-year Morenci electrowinning plant began production in October, and plans were being considered for further expansion.

Phelps Dodge's refinery at El Paso, TX, had a capacity of about 410,000 tons of electrolytic copper per year. Most of Phelps Dodge's refined copper, and additional copper purchased by the company, was cast into rod. Phelps Dodge was the largest domestic producer of copper rod with continuous cast rod facilities in El Paso, TX, and Norwich, CT, that were capable of producing about 386,000 tons of rod per year. Rod sales to outside wire and cable manufacturers constituted about 50% of the company's primary metals sales in 1987.

Copper Powder.—Copper powder production at U.S. manufacturers reached 17.4 million kilograms in 1979 but has declined by about one-half since that time. At the same time, copper powder imports have increased sevenfold. Nonetheless, exports, which were also lower by one-third in 1987 and were lowest in 1983 and 1984 compared with 1979, have continued to be relatively high. U.S. apparent consumption of copper powder decreased from 15.9 million kilograms in 1979 to about 7.3 million kilograms in 1986. Powder metal sales, including copper powder, in North America are heavily dependent upon the automotive industry, which decreased the number of vehicles shipped over the same period. However, U.S. copper powder consumption improved by about 30% in 1987, as U.S. manufacturing of products using powder increased owing to higher demand arising from the decreased value of the dollar. Copper powder consumption was reported from 35 companies in 1987, down from 42 companies reporting copper powder production in 1986. Among those companies reporting to the Bureau of Mines, the largest consumers were General Electric Co., St. Marys Carbon Co., Allied Automotive Co., Chrysler Corp., Stack Pole Corp. and Sintered Metals Inc.

According to Metal Powder Industries Federation shipments data, copper powder usage, including bearings, comprised about 51% of major copper and copper-base powder markets, the total for which amounted to about 16 million kilograms in 1986 and which comprised about 6% of total North American metal powder shipments. Probably the best known use for copper powder was the self-lubricating bearing that was the first major application and still accounted for about 70% of the granular copper powder used. Pure copper powder was also used in the electrical and electronic industries. Copper powder in flake form was used for antifouling paints, decorative and protective coatings, and printing inks. Nonstructural applications included brazing, cold soldering, mechanical plating, metals and medallions, metal-plastic decorative products such as floor tile and epoxy resins, and various chemical and medical applications.

The top three copper and copper alloy powder producers in 1987 were Alcan Metal Powders, Greenback Industries Inc. and SCM Metal Products. The value of U.S. copper powder production comprised only about 2% of the total metal powder sales in the United States, which amounted to nearly $1 billion. Copper powder prices steadily increased in 1987, with commercial-grade copper metal powder reaching $1.55 per

pound on December 21, reflecting adjustments for the escalating cost of copper.

Granular copper powder can be produced by a number of methods, including atomization, electrolysis, hydrometallurgy, and solid state reduction. Each method yields a powder having certain inherent characteristics. Atomization was the preferred commercial production technique used because the powder chemistry, cleanliness, size, and shape can be better controlled than with other methods.

Table 2.—Apparent consumption of copper powder in the United States

Year	Production (kilograms)	Imports		Exports[1]		Apparent consumption[2] (kilograms)
		Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	
1978	16,991,985	220,827	$963	1,712,838	$4,597	15,499,974
1979	17,410,984	241,030	1,048	1,777,112	6,432	15,874,902
1980	13,202,988	185,111	1,144	1,765,621	6,397	11,622,478
1981	13,593,988	292,054	1,309	1,128,977	4,441	12,757,064
1982	9,685,991	874,255	1,198	959,098	3,830	9,101,148
1983	11,454,990	629,988	1,996	785,902	2,799	11,299,076
1984	12,782,989	2,102,952	2,224	881,211	3,379	14,004,730
1985	9,775,991	830,176	1,942	1,111,675	4,020	9,494,492
1986	7,897,993	735,325	1,736	1,367,276	5,353	7,266,042
1987	8,708,992	1,742,450	1,827	1,012,382	11,191	9,439,060

[1]Includes copper flakes.
[2]Production plus imports minus exports.

Source: Bureau of Mines and Bureau of the Census.

Copper Sulfate.—Copper sulfate was produced from copper scrap, blister copper, copper precipitates, electrolytic refinery solutions, and spent electroplating solutions. Imports of copper sulfate, which doubled compared with those of 1986, accounted for an increased share of U.S. consumption. Export data were not available. Tennessee Chemical ceased copper mining and smelting in mid-1987 and by yearend had shifted to using scrap as a basic material in the production of copper sulfate. Kocide Chemical Corp. continued with development of its in situ copper recovery program from the Van Dyke Mine in Miami, AZ. Kocide planned to produce copper precipitate from the leach solutions as a feed material for production of copper sulfate at its Casa Grande, AZ, plant. Data supplied by domestic producers for 1987 indicate that 65% of their shipments were for agricultural end uses, 30% for industrial uses including wood preservatives, and 5% for water treatment.

Table 3.—Copper sulfate producers in the United States in 1987

Company	Plant location
CP Chemicals Inc	Sewaren, NJ, and Sumter, SC.
Kocide Chemical Corp	Casa Grande, AZ.
Madison Industries Inc	Old Bridge, NJ.
Phelps Dodge Corp	El Paso, TX.
Southern California Chemical Co	Santa Fe Springs, CA, Union, IL, Garland, TX.
Tennessee Chemical Co	Copperhill, TN.

Sulfuric Acid Production.—Sulfuric acid was produced as a byproduct of copper smelting. Three copper smelters in Arizona produced a total of 1.1 million tons, and five smelters in New Mexico, Tennessee, Texas, and Utah produced the remainder of 1.5 million tons in terms of 100% sulfuric acid. Although the Tennessee smelter closed at midyear, increased sulfuric acid production occurred as a result of the reopening of the BP Minerals America plant in Utah and better sulfur capture at all plants. Total byproduct sulfuric acid from copper, lead, and zinc smelting amounted to 3.4 million tons in 1987.

CONSUMPTION

U.S. apparent consumption of primary copper and old copper scrap increased by about 4% from that of 1986 to the highest level since the 1982 recession yet remained almost 7% below the peak consumption year of 1979. Domestic production, primary refined copper plus copper recovered from old scrap, rose by about 6% from that of 1986 and accounted for 75% of apparent consumption; domestic inventories, which declined by 50%, accounted for 5%; and net imports of refined copper, which declined by about 6% from the 1986 peak level, accounted for 20% of apparent consumption. According to Bureau of Mines estimates, the end-use distribution for copper was 70% in electrical applications, 15% in construction, 6% in machinery, 4% in transportation, 2% in ordnance, and 3% in other applications. Electrical and electronic uses in all the end uses, except ordnance, were included under electrical applications. The demand for copper in electrical applications, which increased by about 6%, was reflective of the 5% increase in gross private domestic investment, with which there has been a high degree of historical correlation.

Refined copper and copper-base scrap were consumed directly in the manufacture of semifabricated or fabricated shapes and chemicals at approximately 20 wire-rod mills; 40 brass mills; and more than 1,000 foundries, chemical plants, and miscellaneous manufacturers. Reported consumption of refined copper at wire-rod mills, increased by about 6% and accounted for almost 73% of reported consumption of refined copper. Although refined copper consumption at brass mills declined slightly, overall consumption of copper materials increased owing to increased consumption of purchased scrap.

Based on estimates by the Copper Development Association (CDA) from the gross weight of domestic mill shipments and from net imports of mill products, the end-use distribution of copper and copper-alloy mill products consumed in the domestic market in 1987 was construction, 43%; electrical and electronic products, 22%; industrial machinery and equipment, 14%; transportation equipment, 12%; and consumer and general products, including ordnance, 9%. Total brass mill shipments to the U.S. market increased by almost 7%. The largest increase in demand was in the construction sector where shipments increased by about 12%.[27] The increase in construction demand was reflective of an increased intensity of use as housing starts in 1987 declined and the constant dollar value of new construction, according to the U.S. Department of Commerce, increased only by about 1%. In construction, copper and copper-alloy products are used as building wire (electrical), plumbing and heating tube and fixtures, air conditioning and commercial refrigeration, hardware, and miscellaneous uses including roofing, flashing, and various architectural design uses. Demand in all of these uses increased during 1987. Though only a small percentage of the construction market, the use of copper for roofing and architectural purposes, in both new construction and renovations, continued to gain in popularity, resulting in a 20% increase in the miscellaneous sector.

The increased domestic demand for brass mill products was met by domestic production, with mills operating at or near capacity for much of the year. Net imports of brass mill products, according to the Copper and Brass Fabricators Council Inc., declined by 6% to the lowest level since 1984. The low valuation of the U.S. dollar, plus antidumping and countervailing duties imposed on imports of certain sheet and strip products, served to discourage imports and stimulate exports.

Consumption of copper and copper-base scrap increased by about 6% in 1987 as a result of strong demand by the brass mill industry. Increased consumption of scrap at ingot makers and miscellaneous manufacturers was also attributable in part to the strength of the brass mill industry, which reported a 65% increase in the consumption of purchased brass ingot. The tight supply and resulting price increase for refined copper encouraged the use of lower priced copper scrap. Old scrap accounted for about 43% of the copper recovered from scrap.

Over the past 20 years, there has been a marked decline in the domestic ingot-making industry. In the late 1960's, annual domestic production averaged about 300,000 tons compared with an average in the 1980's of about 190,000 tons. The decline in the ingot-making industry paralleled the decline in the domestic foundry industry: Consumption of brass ingot by foundries declined by about 50% over the same time

period. CDA market data indicated that the total foundry product supply to the U.S. market had declined by more than one-third over the past 20 years, principally as a result of substitution by plastics and other materials in the plumbing market. In addition to a fall in demand for their products, domestic ingot makers also have been affected by the transfer of domestic foundry casting capacity overseas, a result of domestic environmental regulations, higher U.S. labor rates, and high material costs. Many of the major domestic suppliers of plumbing fixtures were securing all, or part of, their product line from foreign fabricators.

STOCKS

As a result of a continued world mine production shortfall, stocks of refined copper held by domestic producers and consumers and in COMEX warehouses declined for the fourth consecutive year. By yearend, industry stocks had declined by more than 50% and, at the prevailing rate of consumption, represented less than a 2-week supply. Industry stocks were at the lowest level since the end of the Korean war: At that point, however, the Government stockpile contained about 500,000 tons of copper, compared with 1987 Government stocks of only 20,000 tons.

Most of the decline in domestic stocks was accounted for by a third-quarter drawdown from COMEX warehouses; COMEX stocks by yearend had declined by 80%. During the first 2 months of the year, stocks held in COMEX warehouses actually rose as the new premium for high-grade cathode of 1.5 cents per pound, double the previous premium, attracted more copper into Texas warehouses. At the prevailing producer premiums over COMEX prices, refiners in Texas reportedly found it cheaper to deliver copper to nearby COMEX warehouses than to pay the freight costs to distant consumers. Consequently, a regional disparity developed, with surplus copper available for midwestern consumers and shortages for east coast consumers.

As the copper shortage intensified and merchant and producer premiums increased, copper held at COMEX warehouses declined. COMEX stocks rose only briefly in September as new domestic refinery capacity came on-stream. As competition for spot copper intensified during the fourth quarter, however, exchange stocks plummeted to the lowest level since 1973 and the end of the Vietnam conflict. Similarly, by yearend, consumer stocks, principally at wire-rod mills, had fallen to their lowest level in at least 30 years.

In October, the Commodity Futures Trading Commission intensified its surveillance of the copper commodity market. The small quantity of copper available and the surge in copper price raised concerns of copper price manipulation and insufficient inventories to cover deliveries on expiring contracts. At yearend, no impropriety had been revealed and there was an orderly liquidation of December contracts.

On the London Metal Exchange (LME), there was mounting pressure to eliminate the standard-grade contract owing to its low volume of trade and low liquidity. In April 1986, the LME instituted two new contracts: standard-grade and grade-A. The standard-grade contract appeared to be out of line with the market that was dominated by high-grade copper suitable for wire-rod production.

Interest in the new Mid-America Commodity Exchange copper contract, which had been introduced in June 1986, failed to materialize; by the end of the first quarter, when stocks had been liquidated, the contract became dormant. The new contract, which was comparable to the LME grade-A contract, was intended to be more in line with the physical metal market.

PRICES

The domestic producer price for copper, which had an annual average between 66 and 67 cents per pound over the previous 3 years, and averaged only 65 cents per pound during January 1987, rose throughout the year, peaking at yearend at a record 150.8 cents per pound. The price runup was a result of an increasingly short supply of copper available for purchase on the spot market. The copper shortage was the result of a world mine production shortfall that had persisted over the previous 3 years. Domestic industry stocks of refined copper, which had accumulated to a peak of almost 700,000 tons during the 1982 recession, were drawn down to just over 100,000 tons by yearend. Meanwhile, domestic consumption of copper grew, from a 1983 base, at an annual rate of 1.9%.

At yearend 1986, copper producers and

analysts were still pessimistic about the price of copper, with domestic producers adopting aggressive pricing schemes in an attempt to regain market share. Producer strategies included freight discounts to some delivery points and monthly and quarterly price caps of about 3 cents per pound over the COMEX price. In an effort to remain competitive, foreign producers lowered their premiums; Corporación Nacional del Cobre de Chile (CODELCO-Chile) halved its first quarter COMEX-based premium to 0.75 cents per pound.

Tightness in the copper spot market began to appear early in the year. Producers had secured long-term supply contracts and the new 1.5-cent-per-pound premiums on high-grade copper cathode drew more copper into COMEX warehouses. By May, tightness in the market was clearly evident, with most producers reportedly sold out of spot copper for the remainder of the year; the producer price rose to 80 cents per pound by the second week in July. Factors contributing to the tightness of supply included strong demand during the first quarter, with consumption in March at the highest reported monthly level in almost 8 years; an increase in consumer inventories at wire-rod mills in anticipation of strong demand in the second half of the year; and supply disruptions from Canada and Africa. The price rise was fueled by both a renewed speculative interest in copper markets and a concern that COMEX warehouses could not deliver all the copper held on contract if too many contract holders took delivery rather than liquidate their positions. By May, prices on COMEX had gone into backwardation, with forward sales contracts selling at a slight discount to spot purchases. Prices continued to rise during the second half of the year as domestic inventories declined and demand remained strong.

In November, with industry stocks at a level representing only about a 2-week supply, prices began a dramatic increase as consumers sought to secure copper for the first quarter of 1988. Backwardation of prices on COMEX jumped from 12 cents per pound on 3-month-forward contracts to 24 cents at monthend and to about 50 cents at yearend. Tightness in the domestic market was exacerbated by foreign producers taking advantage of the large spread between the LME price and the COMEX price to ship copper to Europe preferentially and by a declaration of a force majeure for January 1988 shipments by Noranda Copper Co. The LME premium over COMEX, which had averaged only 2.4 cents per pound during the first 10 months of 1987, averaged 10.4 cents in November.

During the first half of the year, domestic dealer buying prices for unalloyed copper scrap generally followed the fortunes of refined copper, with the price spread, or margin, between refined copper and No. 1 scrap remaining constant at about 18 cents per pound. Strong demand by brass mills during the second quarter, as supplies of refined copper became tight, resulted in consumers paying prices for No. 1 scrap at or slightly above the COMEX price for refined copper. As the price of refined copper began its rapid rise at midyear, the margin between scrap and refined copper increased, and by yearend was above 50 cents per pound. The increase in price brought more scrap copper to the market and tended to moderate price increases. The dealer buying prices for alloyed scrap were much slower to respond to the effects of refined price increases and by yearend had only risen by a maximum of about 30%.

WORLD REVIEW

More than one-half of the increase in world mine production of copper was accounted for by North American producers as the United States, Canada, and Mexico added new capacity and/or increased capacity utilization, following rationalization and restructuring of their copper industries. China, Papua New Guinea, and the Republic of South Africa also increased production. In Papua New Guinea, Ok Tedi Mining Co. Ltd. (OTML) started the copper circuit at its gold-copper project. In China, a major concentrator expansion was completed at the Dexing Mine, Jiangxi Province. New world mine capacity added during the year was estimated to be 176,000 tons of copper, to which market economy countries contributed 72%. World mine capacity was estimated to be 9.3 million tons of copper in 1987; market economy countries constituted 83% of the total. Significant production declines were reported by Japan, which resulted mainly from the streamlining of Dowa Mining Co.'s operations that was completed during 1986 and by Spain, which resulted from the closure of Rio Tinto Minera S.A.'s three copper mines. A decision on whether to close permanently the Rio Tinto Mines, which had a combined capacity of about 47,000 tons of copper per year, was not expected until the end of 1988. Rio Tinto's flash smelter and electrolytic refin-

ery continued to operate with imported concentrates.

Development work on several major copper deposits continued. In Australia, the Olympic Dam project was scheduled for a mid-1988 startup. In Chile, negotiations were proceeding to finalize both project financing and concentrate sales contracts for the Escondida project, with final approval of the $1.2 billion project expected in 1988. In Brazil, pilot plant tests on ore from the Salobo deposit reportedly exceeded expectations, and project engineering was under way for development of this deposit by 1992. In Portugal, underground development and construction of the concentrator at the Neves-Corvo project were on schedule and production was scheduled to begin by late 1988 at an annual rate of 1 million tons of ore containing 10% copper.

World smelter production rose by about 2% compared with that of 1986, principally as a result of production from new or expanded smelter capacity in Brazil, China, and Mexico, and from a major smelter in the United States that reopened. Increased concentrate imports allowed production to be increased at Caraiba Metais S.A.'s 150,000-ton-per-year flash smelter in Brazil, which had operated with insufficient feed since being commissioned in 1983. Increased production from the 90,000-ton-of-anode-per-year Guixi smelter in China, which was completed in 1985, was possible owing to increased production at the Dexing Mine. In Japan, although total production from its seven smelters remained at about the same level as that of 1986, production from primary materials rose by about 5%, and stocks of copper concentrates were depleted. Japanese smelters underwent further rationalization during the year as Mitsui Mining and Smelting Co. Ltd. closed its blast furnace as a result of a tolling arrangement made with Nippon Mining Co. Ltd. and Furukawa Co. Ltd. Furukawa halved its production at its Ashio smelter. Belgian smelter production, which was principally from secondary materials, declined by more than 40% owing to tight scrap supplies.

European and Japanese smelters continued to compete for concentrates and to invest in new mining projects in exchange for long-term concentrate supply contracts. In Finland, the state-owned Outokumpu Oy sought to secure concentrates for its Harjavalata smelter. Finland's chronic shortage of copper concentrates was exacerbated by the closure of several Scandinavian mines. In addition, Outokumpu planned to provide loan guarantees for the Escondida project in Chile in exchange for a long-term supply contract (50,000 tons of copper per year in concentrate) and at yearend was negotiating for a large share of Neves-Corvo's concentrates. In Sweden, Boliden AB, whose Ronnskar smelter was threatened with closure owing to environmental constraints and monetary losses, announced plans to invest about $450 million to ensure adequate smelter feed through extending existing mining operations and opening new mines. Boliden operated 17 mines in Sweden, including its Aitik Mine, a 40,000-ton-of-copper-per-year mine that was slated for extension under Boliden's investment plan. Environmental issues remained unresolved because of pending law suits.

Despite the affirmative actions by custom smelters to secure long-term supply contracts, the spot market for custom concentrates was stable throughout the year. Spot Japanese tolling and refining charges averaged about 16 cents per pound of copper. Despite tight supplies, major increases in world smelter consumption of concentrates were generally balanced by increased production at mines.

Even though production from primary materials grew by 3%, world production of refined copper grew by less than 2% as a result of tight scrap supplies. In the United States, primary refined production exceeded the increase in smelter production owing to increased production of electrowon refined copper, which bypassed the smelting process.

Demand for refined copper by market economy countries rose about 3% to a record-high level, according to preliminary data from the World Bureau of Metal Statistics. Consumption increases by North American countries, particularly Mexico and the United States, accounted for about 50% of the world increase in refined copper demand. In South America, refined copper demand in Brazil was reported to have risen by more than 25%. Demand in Western Europe was at about the same level as in 1986, with only small gains or losses reported by most countries. Spain, in particular, showed strong copper demand growth, rising by about 13%. In Asia, significant increases in refined copper consumption were reported in Japan, the Republic of Korea, and Taiwan. In Japan, demand was buoyed by a strong domestic housing market. In the Republic of Korea and Taiwan, demand followed a strong growth trend reflective of the growth in their gross national products.

Table 4.—Estimated production costs at producing copper mines[1]

(January 1987 U.S. dollars per pound of refined copper)

Country	Number of mines	Mine operating cost	Mill operating cost[2]	Smelter-refinery cost[3]	(Less) byproduct credit	Net operating cost[4]	Taxes[5]	Total cash costs[4]	Recovery of capital	Total production cost[4,5]
Australia	3	$0.19	$0.10	$0.32	$0.07	$0.53	$0.01	$0.54	$0.07	$0.60
Canada	14	.28	.24	.33	.32	.53	.02	.55	.11	.65
Chile	7	.15	.19	.09	.06	.37	.01	.38	.04	.42
India	5	.35	.24	.43	.04	.98	.03	1.01	.09	1.10
Peru	5	.20	.24	.34	.05	.73	.02	.75	.12	.87
Philippines	7	.35	.27	.23	.28	.68	.06	.74	.09	.83
United States	15	.19	.28	.14	.10	.51	.02	.53	.05	.58
Zaire	6	.23	.12	.25	.20	.40	.06	.46	.16	.62
Zambia	8	.18	.08	.10	.05	.31	.03	.34	.14	.48
Other	37	.24	.33	.28	.28	.57	.04	.61	.11	.72
Total or average	107	.20	.22	.18	.13	.47	.03	.49	.09	.58

[1]Based on life-of-mine production rates and ore grades. Does not necessarily reflect 1987 operating grade and production.
[2]Includes copper recovery by leaching.
[3]Includes cost of transportation.
[4]Data may not add to totals shown because of independent rounding.
[5]Taxes and production cost are at a zero percent rate of return.

Source: Bureau of Mines, Minerals Availability System (MAS) cost analysis. Prepared by Kenneth Porter.

By yearend, the gap between world demand and refined production increased. Demand for refined copper exceeded production for the fourth consecutive year. As a result, world stocks of refined copper were estimated to have fallen by about 400,000 tons and at yearend, represented only about a 4-week supply at the prevailing rate of consumption. Stocks held in COMEX and LME warehouses alone declined during the year by almost 200,000 tons to a yearend level of only 70,000 tons. The shortfall in production was exacerbated by shipping delays from some of the major copper exporting countries. Rail and port delays were encountered in Africa, as Central African copper exports were shifted from ports in the Republic of South Africa to ports in Mozambique and Tanzania. In Canada, a railroad strike disrupted supply. Consequently, by yearend, the LME price of copper had more than doubled.

The average production cost at the world's producing copper mines, including smelter and refinery charges and recovery of capital, was estimated to be 58 cents per pound, down considerably from the 65 cents estimated for 1986. Net operating costs were estimated to be 47 cents per pound. Some of the lowest costs estimated at the mine and mill level, such as those for Zambia, reflect severe adjustments in exchange rates that effectively lowered the cost. Zambia also had a preponderance of lower cost leach and SX-EW production, which helped to keep its average cost down. The lowest cost producer was Chile, followed by Zambia, the United States, Australia, Zaire, and Canada.

Australia.—Mine production declined for the second consecutive year owing to decreased output from Australia's two largest mines, the Mount Isa Mine (Mount Isa Mines Ltd.) and the Lyell Mine (Renison Goldfields Consolidated Ltd.), as well as to the closure of several mines. The Mount Gunson Mine (EMAC Gunson Partnership) closed in mid-1986, and the small Warego Mine (Peko-Wallsend Ltd.) closed in early 1987. Even so, smelter production increased as Mount Isa increased smelter capacity through incorporation of the Isamelt process. Refinery production increased owing to expanded production at the Townsville refinery.

The joint venture between Cyprus Minerals Australia Co. (37.5%), Arimco NL (37.5%), and Elders Resources Ltd. (25%), announced its intention to develop the Starra copper-gold deposit, which was about 145 kilometers southeast of Mount Isa. The Starra project was slated to begin production in early 1988 and to produce 10,000 tons of copper in concentrate per year. To date, 4.6 million tons of ore, with an average grade of 2.05% copper and 5.2 grams of gold per ton, had been identified.

Barrack Mines Ltd. announced its intention to develop the deeper, polymetallic ore at its Horseshoe gold mine in Western Australia. A plant to produce about 17,000 tons of copper in concentrate was under construction and was scheduled to begin production in early 1988. Ore reserves of at least 930,000 tons, with a grade of 8.4% copper, 22 grams of silver per ton, and 1.4 grams of gold per ton, had been delineated.

Construction of the Olympic Dam copper-gold-silver-uranium project at Roxby Downs Station, South Australia, was progressing toward a mid-1988 startup date. The initial annual production rate was to be 30,000 tons of copper; the smelter and refinery were to begin operation during the fourth quarter of 1988.

Exploration of a number of base metal projects continued during the year, including the Thalanga deposit in Queensland, which reportedly had estimated ore reserves of more than 7 million tons containing 2.2% copper, 11.4% combined lead and zinc, 71 grams of silver per ton, and 0.47 gram of gold per ton. Preliminary studies for a 600,000-ton-of-ore-per-year plant reportedly were completed.

Canada.—Mine production of copper rose by 10% to a record-high level, while smelter and refinery production remained at about the same level as that of 1986. Smelter and refinery production were negatively affected by a strike at Noranda's Horne smelter, which began in November 1986 and continued through the first quarter of 1987, and by a railroad strike that occurred during the fourth quarter of the year and impeded the flow of smelter and refinery feed materials. Consequently, exports of ores and concentrates rose by almost 8% to record levels, while exports of refined copper declined. Domestic demand for refined copper rose by more than 10%, buoyed by strong brass mill demand and exports of brass mill products.

Mine production was regionally divided, principally between the western Province of British Columbia, which accounted for 45%

of Canadian production, and the central and eastern Provinces of Ontario, Manitoba, and Quebec, which accounted for 37%, 9%, and 7% of production, respectively. In British Columbia, Highland Valley Copper Co. (HVC), Canada's largest copper mine producer, which was formed last year through the merger of Cominco Ltd.'s Highland Valley area assets with those of Lornex Mining Corp. Ltd., completed installation of two semimobile, in-pit crushers and an associated 5-kilometer belt conveyor system. The new system, which was completed at yearend at an estimated cost of $44 million, linked Cominco's high-grade Valley Pit with the modern Lornex Concentrator and was expected to substantially reduce costs. HVC reportedly became the most competitive copper operation in Canada. In 1987, HVC processed 42 million tons of ore with an average grade of 0.43% copper to yield 86,000 tons of copper in concentrate; 90% of the ore was processed at the Lornex mill, and the remainder was processed at the Valley mill. Under the new production plan, the Lornex Pit will supply the Lornex Concentrator with only about 15% of its ore, while about 30,000 tons of ore per day from the Valley Mine will be trucked from the conveyor transfer point to Cominco's Bethlehem concentrator. In September, Teck Corp. reached an agreement with the HVC partners to merge its Highmont Mining Corp.'s mill facilities into HVC. Cominco will reportedly relinquish 5% of its 55% share to Teck in exchange for a cash payment from HVC. The acquisition would reportedly allow for the eventual closing of the Bethlehem mill in favor of the Teck mill. Afton Mining Corp. depleted the ore reserves in its main pit, but continued operations from stockpiled ore and from its Pothook Pit, which was to be depleted in 1989.

In Ontario, Falconbridge Ltd. completed the expansion of smelting and refining operations at Kidd Creek to 92,000 tons of copper per year. The smelter was closed for 5 weeks during the fourth quarter for maintenance and modifications related to the expansion.

In Manitoba, Sherritt Gordon Mines Ltd.'s Ruttan Mine was sold to Hudson Bay Mining and Smelting Co. Ltd., effective July 30. Sherritt Gordon, which had reported losses in 1986, had considered closing the mine, which supplied almost 80% of purchased concentrates and 30% of total feed to Hudson Bay's Flin Flon smelter.

In Quebec, Noranda reached an agreement with the Provincial Government to build an acid plant at its Horne smelter to cut sulfur dioxide emissions in half, to 300,000 tons per year. The Federal and Provincial Governments were expected to pay one-third each of the estimated $95 million cost for building the acid plant, which was expected to come on-stream by 1990. In April, a fire at Noranda's underground Gaspé Mine closed the mine indefinitely. The associated smelter, which had an annual capacity of about 65,000 tons of copper, continued operating using stockpiled and tolled concentrates. Minnova Inc., formerly Corporation Falconbridge Copper, was proceeding with its development of the Ansil and Winston Lake properties. Ansil, which had indicated ore reserves of 2 million tons with an average grade of 7.1% copper, 0.5% zinc, and 0.8 ounce of silver per ton, was expected to start production in 1989 at a rate of about 500,000 tons of ore per year. The Winston Lake zinc-copper mine, which had an average ore grade of 16% zinc and 1% copper, was expected on-stream in 1988. It was designed to process 350,000 tons of ore per year. Les Mines Selbaie anncunced its intention of developing the third ore body at Selbie, Quebec. The development of its A-2 underground zone, which had an average grade of 2.24% copper, 1.04% zinc, 1.23 grams of gold per ton, and 19.4 grams of silver per ton, will extend the mine life by about 4 years.

Chile.—Copper production increased slightly despite a decline in production by state-owned CODELCO-Chile, the world's largest copper-producing company. CODELCO-Chile reported producing 1.09 million tons of copper, 11,500 tons less than its 1986 record-high production. However, even though production of copper declined, production of byproduct molybdenum increased slightly. Copper production at CODELCO-Chile's four producing divisions fell short of projections because of extenuating circumstances relating to severe winter weather conditions, and to the high arsenic content and declining grade encountered in the Chuquicamata ore. Because of the high arsenic content, CODELCO-Chile reportedly exported some of Chuquicamata's concentrates for processing. CODELCO-Chile's sales program had called only for sales of some Andina concentrates. CODELCO-Chile reported record-high pretax revenues of about $730 million, an increase of about 80% over that of 1986. Copper sales in-

creased by about 2% to 1.16 million tons, 40% of which went to Western Europe, 23% to South America, 22% to Asia, 13% to North America, and 2% to other destinations. Electrolytic grade cathode, or wirebar, accounted for 55% of their sales; fire-refined copper, 14%; and unrefined copper, 31%.[28]

In 1987, CODELCO-Chile reported investing $323 million in plant improvements and equipment, in part to expand capacity and in part to compensate for declining ore grades and higher operating costs. At its Tocopilla powerplant, which was spun off from the Chuquicamata Div. to form a fifth operating division, a major investment in a pier and in coal-handling facilities was completed. The new unloading installation can handle up to 1,500 tons of coal per hour. A new power generator, intended to meet the additional power requirements of expansion projects at Chuquicamata, was commissioned in July. At Chuquicamata, milling capacity was being increased by 50% to 153,000 tons of ore per day, work was progressing on a 51,000-wet-ton-per-day concentrator expansion, a new anode casting facility was completed, and a new flash furnace and acid plant were under construction. An expansion of materials-handling facilities, including a waste crushing and conveying system at the mine, was nearly complete, as was a 275,000-ton-per-year expansion of the electrolytic refinery. The expansion plans were geared at not only expanding annual output to about 750,000 tons of copper per year, but also at compensating for a declining ore grade, which was expected to fall from 1.6% copper to 1.0% copper by 2000. The new flash smelter and acid plant, the refinery expansion, and a waste-dump leaching project were all planned for operation in 1988. Excess acid production was expected to be sold at up to a 70% discount from the prevailing market rates as a Government stimulus to the small- and medium-size mining sectors for exploitation of oxide reserves through leaching.

At the El Teniente Div., work on expanding the underground mine into the Mina Sur and Mina Norte sectors progressed for the purpose of increasing ore production by 20% to 110,000 tons per year by 1991. The expansion was necessary to maintain production levels because the more friable, secondary-enriched ore was nearing depletion and ore grades had fallen from 1.8% in 1980 to 1.4% copper. The mine was also shifting to more mechanized block-caving methods in order to cope with the harder ore. The new dam at Caren began receiving tailings through a gravity-fed, 85-kilometer, concrete flume. At the Calcetones smelter, the first of several new and enlarged, El Teniente-type, modified converters was installed as part of an expansion plan that was aimed at keeping pace with increased mine production and lower concentrate grades. At the Andina Div., the tailings dam was augmented to increase disposal capacity as mine capacity was increased. At the El Salvador Div., a new mechanized loading facility was commissioned at the Port of Chanaral, and an oxygen plant was installed at the Porterillos smelter to boost capacity.

Empresa Nacional de Minería (ENAMI), the state-owned custom mineral processor, which served the small- and medium-size private mining sector, operated four concentrators, two smelters, and a refinery. As a custom processor, it was able to handle a wide variety of ores and concentrates. In 1987, it reported a record-high revenue of $662 million and profits of $30.1 million. The rise in copper prices in 1987 allowed for suspension of the price-support system early in the year and for mining companies to begin repayment of debt accrued to ENAMI since 1983. Production of refined copper by ENAMI rose by more than 15% to about 200,000 tons, following completion of an expansion project in 1986 at its Ventanas refinery. At midyear, ENAMI announced approval for the construction of a 290,000-ton-per-year sulfuric acid plant and an oxygen plant at its Ventanas smelter. These plants, expected to be completed in 1989, reportedly will increase smelter capacity by an estimated 180,000 tons of concentrates per year and will allow ENAMI to become an exporter of sulfuric acid. The expansion will eliminate the imbalance between ENAMI's smelting and refining capacity. Previously, excess refinery capacity had allowed ENAMI to toll refine blister copper from CODELCO-Chile and others. Financing for the project, estimated to cost $72 million, was to come from the Federal Republic of Germany.

At yearend, development plans for the Escondida copper project were well under way. Interdependent negotiations were taking place to secure both financing for the project and guaranteed markets for the production. Escondida, which was owned 60% by The Broken Hill Pty. Co. Ltd. of Australia, 30% by the Rio Tinto Zinc Corp.

Ltd., and 10%, by a Japanese consortium headed by Mitsubishi, was expected to produce up to 300,000 tons of copper in concentrates per year and to cost $1.2 billion for development. In addition to the sulfide ore body, feasibility studies were being conducted on the potential for exploitation of the oxide reserves.

Cia. Minera Disputada de las Condes S.A., a subsidiary of Exxon Minerals Corp., completed its $68 million expansion of its mine, mill, and concentrator, which since 1985 had raised production from 5,500 tons of ore per day to more than 11,500 tons per day. Exxon planned to increase total annual production from its El Soldado and Disputada Mines by about an additional 50% to 140,000 tons of contained copper by 1990.

In November, Dallhold Resources Inc., a subsidiary of the Alan Bond group of companies in Australia, purchased Cia. Minera San José Ltda., which was operator of the El Indio and adjacent El Tambo gold-silver-copper mines. Proven reserves at the two mines included 6.7 million tons of ore containing 4.5% copper, 7 grams of gold per ton, and 90 grams of silver per ton. Copper production from the two mines was about 15,000 tons in 1987.

Mexico.—The two major copper mines, La Caridad, owned by Mexicana de Cobre S.A., and Cananea, owned by Cia. Minera de Cananea S.A., accounted for more than 97% of Mexico's copper mine production. Cananea increased production, having completed a major mine expansion program in 1986. Smelter production was also about 35% higher, owing to startup of a new flash smelter at La Caridad in 1986. However, the smelter, which was built to handle all of La Caridad's 1,800 tons of concentrates per day, was experiencing significant startup problems and operated at less than 50% of capacity. A sulfuric acid plant, with a projected capacity of 2,500 tons per day of 93% sulfuric acid, was under construction with commissioning planned for 1988. On January 29, the Governments of Mexico and the United States signed an agreement to limit copper smelter emissions along their common border. The agreement limited sulfur dioxide emissions from the La Caridad smelter to a maximum of 0.065% by volume, as averaged over any 6-hour period, beginning June 1, 1988. A similar limit would apply to the Cananea smelter should it be expanded.

At the Cananea Mine, capacity was being expanded through the new SX-EW plant, which will have a capacity of 20,000 tons of cathode per year and will supplement its existing construction of a 10,000-ton-per-year facility. The mill-head grade at Cananea was improved by segregating the low-grade ore, which contained 0.15% to 0.45% copper, for leaching. To balance mine and smelter production, Cananea purchased the 15,000-ton-per-year Santa Rosalia smelter at Baja. Some of Cananea's concentrates were to be processed at the Santa Rosalia smelter once renovations were complete.

As a result of strong domestic demand for refined copper, which increased by more than 30% in 1987, and a shortfall in domestic smelter production, Mexico was a net importer of refined copper. Mexico's only electrolytic copper refinery, which was owned by Mexicana de Cobre, operated at less than two-thirds of its rated 150,000-ton-of-copper-per-year capacity owing to a shortage of anode copper from its smelters.

Papua New Guinea.—Mine production increased by more than 20% as a result of the commissioning of the copper circuit in June at OTML's gold-copper project. However, startup problems caused copper production to be short of the planned 1,000 tons of concentrates per day, which averaged about 28% copper. OTML had planned to produce 180,000 tons of concentrate in 1987, 400,000 tons in 1988, and following completion of the concentrator expansion, up to 700,000 tons per year in 1992 and 1993. By midyear, Metallgesellschaft AG of the Federal Republic of Germany, which was OTML's sales agent, had negotiated supply contracts for most of the concentrate production. A Japanese consortium was to receive 60,000 tons of concentrate in 1987 followed by 230,000 tons per year over the next 6 years; the Korean Mining and Smelting Co. was to receive 30,000 tons per year over the next 5 years; and West Germany's Norddeutsche Affinerie AG was to receive 25,000 tons in 1987, increasing to 150,000 tons per year in 1988. OTML was reportedly experiencing cash-flow problems during the year and dropped its in-house feasibility study for construction of its own copper smelter.

Because of the mining of a section of lower grade ore, production at Bougainville Copper Ltd. declined slightly to 178,000 tons of copper in concentrates. Ore grade for the year reportedly averaged 0.42% copper. Bougainville completed construction of a preconcentration screening plant during the third quarter, which helped to boost

production. Since its Panguna deposit was expected to be exhausted by the year 2000, Bougainville was seeking to have a Government moratorium on exploration rescinded. By yearend, a detailed engineering study for constructing a gravity-flow slurry pipeline, reportedly planned to be the world's largest and longest, had been completed. If constructed, the pipeline, estimated to cost $50 million, would transport tailings 32 kilometers from the concentrator to the Solomon Sea and would replace the existing river transport system.

Peru.—A 23-day strike in November at the Cuajone and Toquapala Mines of Southern Peru Copper Corp. (SPCC) cut production. In addition to SPCC's mines, owned 52% by Asarco, the strike also affected the Government-owned Ilo refinery, which refined all of SPCC's copper. Strikes at Empresa Minera del Perú's (Minero Perú) Cerro Verde Mine and Empresa Minera Especial Tintaya S.A.'s Tintaya Mine also reduced production.

Tintaya was considering several moves to expand its production including the possible treatment of 7.5 million tons of stockpiled oxide ore through the sulfide concentrator. The Government Institute of Geology and Metallurgy reportedly was testing the material for concentrator treatment. Tintaya also installed particle-size monitors and other equipment to enhance recovery and improve concentrate grade. Tintaya was negotiating with Minero Perú for the underground development of the Coroccohuayco deposit, which was near the Tintaya Mine and reportedly had proven ore reserves of at least 15 million tons with a grade of 3% copper. Production from the Coroccohuayco deposit was to start by mid-1990 at a rate of 61,000 tons of concentrate per year.

Minero Perú conducted a feasibility study for a combined leach process using concentration- and bacterial-leaching technologies to solve permeability problems that were encountered in sulfide ore leaching at Cerro Verde. The current leach process had been used to process oxide ores that were nearing depletion. The combined process would require a $35 million investment in new milling and flotation equipment and would involve finer grinding of the ore with segregation of the fines for concentration.

SPCC was increasing efforts to reduce costs, having barely broken even in 1987 despite the improved copper and silver prices, owing to declining ore grades at its Cuajone Mine, high tolling charges by the state-run refinery, and high fuel import tariffs. Improvement plans called for at Cuajone were the installation of column flotation cells for the treatment of about 80 to 100 million tons of sulfide ore dumps with bacterial leaching and SX-EW recovery. Plans also called for reorganization of SPCC management.

Philippines.—Mine production in the Philippines declined slightly in 1987. A 16% increase in production by the Philippine's largest producer, Atlas Consolidated Mining Development Corp., was offset by production declines at the six other copper-producing companies. Despite the rise in copper prices, most Philippine copper producers continued to lose money. Marcopper Mining Corp., with production of 24,000 tons of copper, was threatened with closure unless it could restructure its debt and secure financing for development work. Bond Corp. Holdings Ltd. negotiated throughout the year with Atlas in an effort to obtain a 40% equity in Atlas through assumption of existing loans and for additional loans to be used for exploration and development of the Masbate gold mine. At yearend, loan repayment terms with Atlas's creditors were still unresolved. Lepanto Consolidated Mining Co. Inc. and Galactic Resources Ltd. of Canada announced a joint venture to develop the Far South East deposit, a major copper-gold deposit at Mankayan, Benquet Province. Drilling had thus far delineated more than 290 million tons of ore at the Far South East deposit reportedly containing more than 2 million tons of copper. A feasibility study was scheduled for completion in early 1988.

Philippine Associated Smelting and Refining Corp.'s smelter and refinery at Isabel, South Leyte, which were 40% state-owned through the National Development Corp., announced plans to increase its 138,000-ton-per-year copper capacity by 25%. The cost of the expansion program was estimated at $51 million and was not expected to be completed until at least 1989. In June, the company received Government approval to import, for the first time, 40,000 tons of copper concentrates from Papua New Guinea. The smelter was shut temporarily in March and again in April, first due to power problems and later to allow for repairs.

Zaire.—Copper production in Zaire was from the state-owned company, La Générale des Carrières et des Mines du Zaire (Gécamines), which operated about a dozen mines grouped in three geographic regions

along the copperbelt of Central Africa: Kolwesi (western), Likasi (central), and Lumbubashi (southern). At the end of April, the state-owned Société de Développement Industriel et Minière du Zaire (Sodimiza), which operated two underground mines, was incorporated into Gécamines. Sodimiza had been owned by a Japanese consortium until 1983. Gécamines was proceeding with its 5-year, $870 million investment program, which was started in 1985 to rehabilitate its copper industry. Equipment tenders had been submitted for a new 100,000-ton-per-year refinery at Kolwezi. The refinery, which was planned for completion in 1990, was expected to save $20 million per year in foreign exchange from elimination of tolling costs. Rehabilitation of the Kolwezi concentrator was expected to be completed by 1989, and a mobile in-pit crushing and belt-conveying system for the Kolwezi open pits was expected to be completed by 1990.

Zambia.—The 5-year reorganization plan announced in 1986 by Zambia Consolidated Copper Mines Ltd. (ZCCM), the state-controlled company responsible for all of Zambia's output, began to show a positive impact with mine production rising slightly. In August, ZCCM closed its unprofitable Chambishi underground mine and concentrator; open pit mining began at Chambishi in 1965. Output from the Nchanga Div. was not affected as output from the higher grade Konkola Mine was increased to compensate for lower output at Chambishi. Meanwhile, work was progressing on three underground projects at Mufulira, ZCCM's largest underground mine, which had a capacity of about 80,000 tons of recoverable copper per year. The Mufulira projects were geared toward accessing additional ore reserves and included deepening of the access shaft, extension of conveyor and service shaft inclines, and installation of an underground crusher. Ore reserves at Mufulira were estimated to be 81 million tons with an average grade of 3% copper.

In March, in an attempt to restructure its economy, which was largely dependent on copper exports, Zambia announced its intention to break with the austerity measures that had been imposed by the International Monetary Fund, and its intention to cut foreign debt service repayment. Under the new payment plan, the foreign exchange requirements of ZCCM and other state-run industries would be deducted from earnings prior to calculating its debt repayment, which was based on a percentage of earnings. This and other measures, which included cessation of the mineral export tax beginning in 1988, were geared toward ensuring the necessary capital to revitalize Zambia's mineral industry. Zambia also was seeking to halt its dependence on the Republic of South Africa's railroad system. Early in the year it halted all copper shipments through the Republic of South Africa, rerouting all copper shipments through the ports of Dar Es Salaam, Tanzania, and Beira, Mozambique. In April, Angola, Zaire, and Zambia signed a letter of intent to reopen the crippled Benguela Railway leading to the Angolan Port of Lobito. The estimated cost of rehabilitating the Benguela Railroad, which had been shut for 12 years because of destruction during the Angolan civil war, was estimated to be $280 million.

TECHNOLOGY

The first in a planned series of international conferences devoted to technical and economic developments in the copper industry took place in Viña del Mar, Chile, from November 30 to December 3, 1987. The "Copper 87" conference provided a forum for discussing both the outlook for the industry and recent advances in various technical aspects of copper processing. Papers given at the conference were published in four volumes, dealing with subjects in hydrometallurgy, pyrometallurgy, mineral economics, and mineral processing and control.[9] Several authors thought that the copper industry was not spending nearly enough on research and market development.

A comprehensive review of flash smelting was published. The authors found the flash furnace particularly interesting because it oxidizes its raw material (Cu-Fe-S concentrate) to provide part of its energy requirement; it can be operated in many ways (e.g., autogenously with oxygen blast or fossil-fuel assisted with air blast) depending upon the goals of the operator. The book described flash smelting in general, the Outokumpu and Inco flash smelting processes in particular, and included a section in which the flash smelting process was described mathematically. The mathematical section described a set of mass- and heat-balance

equations that can be used to describe steady-state smelting under autogenous or near-autogenous smelting conditions. These equations can be used to determine the amounts of blast, flux, and fuel inputs to be employed for achieving a smelting goal and for optimizing and controlling the flash smelting process.[40]

The Bureau of Mines signed a Memorandum of Agreement with the Casa Grande Copper Co. for a cooperative project to help the copper company determine whether in situ mining techniques can be used at its Casa Grande West project and Santa Cruz sites in Arizona. The company was to share hydrological and geological data with the Bureau, and Bureau scientists were to evaluate the information in terms of in situ mining requirements. The Bureau was also working with two other copper companies in the Casa Grande area, evaluating potential sites for future in situ mining projects.

Significant progress has been made in recent years in copper SX-EW plant design. Continuing pressure to reduce costs and increase productivity has promoted the need for a new generation of plants. The Dremco process for electrowinning reportedly was producing a high-quality copper from a solvent extraction electrolyte.[41] The process utilized high-current-density technology, resulting in increased productivity, lower costs, and a high-purity product. Full-scale testing of the Dremco process at a copper producer's plant proved the viability of the process, demonstrating that more copper could be produced for lower cost than through conventional plants. A plant using the Dremco technology would be one-third the size of a conventional plant. The use of rigid permanent cathode blanks, precise electrode alignment, and air agitation resulted in very dense, smooth, and pure cathodes with high tensile strength.

Progress was made in the development of the new ceramic, high-temperature, copper-oxide-base, superconducting materials. In 1986, IBM Corp. researchers in Switzerland made a breakthrough in superconductivity research with copper-oxide-base materials mixed with barium and lanthanum. Prior to their discovery, superconductivity, a state in which electrical current can pass through a solid without resistance, had only been achieved at temperatures approaching absolute zero (-272° C). The highest critical temperature of record was only -250° C, or 23 K. The extreme temperature, which required cooling with expensive liquid helium, limited the application of superconductive materials. Despite the growing use of conventional superconductors in highly specialized applications, there were still many technical barriers to the practical use of superconducting materials.[42]

In 1987, researchers at the University of Houston and University of Alabama discovered that a different ceramic copper oxide, mixed with barium and yttrium, would superconduct at up to 94 K, allowing it to be cooled with significantly less expensive liquid nitrogen. Westinghouse Electric Corp. announced development of a process for producing superconducting powders that could simplify fabrication. The process produced very fine, pure powders, largely composed of single crystals that could be magnetically aligned to give them the orientation necessary to boost current density. The new process was used to make yttrium-barium-copper oxide compounds that superconduct when cooled to about 95 K, or -178° C.[43] In addition, a bismuth-strontium-copper oxide compound was produced with transition temperatures about 95 K. By late 1987, researchers in Arkansas had announced their discovery of a thallium-barium-copper oxide material that achieved zero resistance to electrical current at 81 K, and later, by adding calcium, a new material was produced that retained zero resistance at temperatures up to 106 K.[44]

Most potential applications of superconductors can be divided into two broad categories. The first are those used for large technological systems, either in the form of wire for the transmission of electricity, or in magnets. Examples of these include magnetically levitated trains, high-energy accelerators, energy-storage systems, and nuclear magnetic resonance imaging machines. The second category involves use as "thin films" in small-scale electronic devices similar to semiconductor chips. It was expected that the new ceramic superconductors should have more immediate impact in this application. However, until there is a breakthrough allowing superconductors to operate at room temperature, the transformation of these technologies by superconductor materials was expected to happen slowly.

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[2]All quantities in this chapter are given in metric tons unless otherwise specified.
[3]Foundry Magazine. Washington Update. 1987, p. 12.
[4]American Metal Market. ICC Rules Railroads Delayed Nonferrous Metal Rate Cuts. V. 95, No. 95, May 18, 1987, pp. 1, 8.
[5]ASARCO Incorporated. Operations Data Sheets. Pres. at Sulfur Inst. Annu. Meet., Washington, DC, Jan. 1988; available upon request from J. L. W. Jolly, BuMines, Washington, DC.
[6]Joklik, G. F. Cost Reduction at Bingham Canyon. Pres. at Capital Met. Forum, Washington DC, Nov. 18, 1987; available upon request from J. L. W. Jolly, BuMines, Washington DC.
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[8]American Metal Market. Magma Goal: Cut Production Costs. V. 95, No. 182, Sept. 18, 1987, pp. 1, 8.
[9]Phelps Dodge Corp. 1987 Annual Report. P. 4.
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[11]ASARCO Incorporated. 1987 Annual Report. P. 14.
[12]BP Minerals America. 1987 Annual Report. P. 22.
[13]Cyprus Minerals Co. 1987 Annual Report. P. 1.
[14]Inspiration Resources Corp. 1987 Annual Report. P. 2-9.
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[16]Tribune (Great Falls, MT). Butte Mines May Turn $1.4 Million Profit in '87. May 30, 1987, p. 4.
[17]Montana (Butte) Standard. MRI on $100 Million Profit Report: "We Wish." May 6, 1988, p. 2.
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[19]Page 59 of work cited in footnote 12.
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[21]Cyprus Minerals Co. 1987 10K Annual Report. P. 4.
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[23]Page 4 of work cited in footnote 21.
[24]Page 28 of work cited in footnote 14.
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[27]Magma Copper Co. 1987 Annual Report. P. 1.
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[29]Montana (Butte) Standard. Montana Resources Marks First Year of Operation. July 15, 1987, p. 2.
[30]Pay Dirt. Sharon Steel's Continental Copper Mine Awaits a Better Day. Nov. 1987, p. 10A.
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[33]Pay Dirt. Magma's San Manuel Smelting Furnace To Be World's Largest. June 1987, p. 6B.
[34]Mining Magazine. Flue Dust Processing at Anaconda. Aug. 1987, p. 107.
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[36]Pages 8 and 9 of work cited in footnote 14.
[37]Copper Development Association. Annual Data 1988, Copper Supply & Consumption, 1967-1987. Greenwich, CT, June 1988, 20 pp.
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Table 5.—Percentage of copper ore and recoverable copper extracted from open pit and underground mines in the United States

Year	Open pit		Underground	
	Ore	Copper[1]	Ore	Copper[2]
1983	89	85	11	15
1984	92	87	8	13
1985	88	89	12	11
1986	87	86	13	14
1987	88	84	12	16

[1]Includes copper from dump leaching.
[2]Includes copper from in-place leaching and copper recovered from tailings and as a byproduct from other sources.

Table 6.—Mine production of recoverable copper in the United States, by month and by State

(Metric tons)

	1983	1984	1985	1986	1987
Month:					
January	90,025	92,971	92,699	99,029	102,200
February	77,664	87,883	87,089	87,365	93,040
March	89,274	96,124	100,170	96,386	107,134
April	84,646	91,250	93,641	93,838	99,284
May	92,170	95,045	96,834	97,116	105,087
June	89,717	9[illegible],900	90,225	96,561	102,487
July	76,323	88,2[illegible]	90,711	95,151	105,028
August	79,211	89,032	87,446	94,506	108,286
September	86,704	88,074	81,898	97,572	106,364
October	89,608	94,382	94,222	100,185	105,886
November	93,706	92,507	91,870	92,452	109,677
December	89,050	89,130	98,953	97,026	111,441
Total	1,038,098	1,102,613	1,105,758	1,147,277	1,255,914
State:					
Alaska	W				
Arizona	678,216	746,452	796,556	789,175	764,148
California	W	W	W	W	
Colorado	W	W	W	W	W
Idaho	[illegible]556	3,701	[illegible]51	W	W
Illinois			[illegible]	W	W
Michigan			[illegible]	W	W
Missouri	[illegible]	[illegible]	[illegible]	W	W
Montana	[illegible]	[illegible]	[illegible]	W	W
Nevada	[illegible]	W	[illegible]	W	
New Mexico	[illegible]	W	[illegible]	W	W
Oregon	[illegible]				
Tennessee	[illegible]	[illegible]	W	W	W
Utah	[illegible]	W	W	W	W
Washington	[illegible]				W
Total	[illegible]	[illegible]613	1,105,758	1,147,277	1,255,914

W Withheld to avoid disclosing company data; included with "Total."

Table 7.—Twenty-five leading copper-producing m[illegible]n the United States in 1987, in order of output

Rank	Mine	County and State	Operator	Source of copper
1	Morenci	Greenlee, AZ	Phelps Dodge Corp	Copper-molybdenum ore, concentrated and leached.
2	Tyrone	Grant, NM	Phelps Dodge Corp. and Cyprus Chief Copper Co.	Copper ore, concentrated and leached.
3	Bingham Canyon	Salt Lake, UT	Kennecott, Utah Copper Div	Copper-molybdenum ore, concentrated and leached.
4	San Manuel	Pinal, AZ	Magma Copper Co	Copper-molybdenum ore and retreated slag, concentrated and leached.
5	Chino	Grant, NM	Chino Mines Co	Copper-molybdenum ore, concentrated and leached.
6	Ray	Gila, AZ	ASARCO Incorporated	Copper ore, concentrated and leached.
7	Bagdad	Yavapai, AZ	Cyprus Bagdad Copper Co	Copper-molybdenum ore, concentrated and leached.
8	Sierrita	Pima, AZ	Cyprus Sierrita Corp	Do.
9	Pinto Valley	Gila, AZ	Pinto Valley Copper Corp	Do.
10	White Pine	Ontonagon, MI	Copper Range Co	Copper ore, concentrated.
11	Inspiration	Gila, AZ	Inspiration Consolidated Copper Co.	Copper-molybdenum ore, concentrated and leached.
12	Mission Complex[1]	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
13	Continental	Silver Bow, MT	Montana Resources Inc	Copper-molybdenum ore, concentrated.
14	Troy	Lincoln, MT	ASARCO Incorporated	Silver-copper ore, concentrated.
15	Casteel	Iron, MO	The Doe Run Co	Lead-copper ore, concentrated.
16	Ox-Hide	Gila, AZ	Inspiration Consolidated Copper Co.	Copper ore, leached.
17	Silver Bell	Pima, AZ	ASARCO Incorporated	Do.
18	Copperhill (1 mine).	Polk, TN	Tennessee Chemical Co	Copper-zinc-iron-sulfide ore, concentrated.
19	San Xavier	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.
20	Miami	Gila, AZ	Pinto Valley Copper Corp	Copper ore, leached.
21	Viburnum No. 29	Washington, MO	The Doe Run Co	Lead ore, concentrated.
22	Mineral Park	Mohave, AZ	Cyprus Minerals Co	Copper ore, leached.
23	Magmont	Iron, MO	Cominco American Incorporated	Lead-zinc ore, concentrated.
24	Buick	do	The Doe Run Co	Lead ore, concentrated.
25	Copper Queen	Cochise, AZ	Phelps Dodge Corp	Copper ore, leached.

[1]Includes Eisenhower, Mission, and Pima.

Table 8.—Mine production of copper-bearing ores and recoverable copper content of ores produced in the United States, by source and treatment process

(Metric tons)

Source and treatment process	1983		1984		1985		1986		1987	
	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper	Gross weight	Recoverable copper
Mined copper ore:										
Concentrated[1]	171,776,000	810,090	168,226,000	883,338	160,258,000	906,438	166,891,000	909,136	201,434,000	1,005,706
Leached[2]	6,154,000	104,991	3,588,000	106,597	1,952,000	98,453	2,347,000	135,448	1,198,000	161,591
Total	177,930,000	915,081	171,814,000	989,935	162,210,000	1,004,891	169,238,000	1,044,584	202,632,000	1,167,297
Copper precipitates shipped; leached from tailings, dump, and in-place material	130,857	89,274	120,437	80,845	118,096	82,948	111,050	79,031	109,520	69,376
Miscellaneous:										
Silver ore	4,483,000	19,384	4,487,000	22,334	1,041,000	3,745	560,000	2,599	275,000	1,155
Lead ore	7,303,000	7,725	4,748,000	5,818	6,433,000	13,410	3,336,000	7,405	W	4,463
Other copper-bearing ores[3]	9,970,000	6,634	22,821,000	3,681	8,898,000	764	2,447,000	13,658	7,980,000	13,623
Grand total	XX	1,038,098	XX	1,102,613	XX	1,105,758	XX	1,147,277	XX	1,255,914

XX Not applicable. W Withheld to avoid disclosing company proprietary data.

[1]Includes the following methods of concentration: dual process (concentration followed by leaching) and froth flotation.

[2]At least 85% of leached ore processed by electrowinning. Actual figures are as follows: 1983—101,936; 1984—100,180; 1985—90,439; 1986—125,352; and 1987—157,986 tons of electrowon copper (see table 11).

[3]Includes copper-lead ore, gold ore, gold-silver ore, lead-zinc ore, molybdenum ore, tungsten ore, zinc ore, fluorspar, flux ores, cleanup, and tailings.

Table 9.—Recoverable copper, gold, and silver content of concentrated copper ore in 1987

State	Ore concentrated (thousand metric tons)	Recoverable metal content				Value of gold and silver per metric ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Metric tons	Percent			
Arizona	131,756	607,238	0.46	48,430	3,529,883	$0.35
Other[1]	69,678	398,468	.57	212,798	11,800,837	2.56
Total or average	201,434	1,005,706	.50	261,228	15,330,720	1.11

[1]Includes Idaho, Michigan, Montana, New Mexico, Tennessee, and Utah.

Table 10.—Blister and anode copper produced in the United States, by source of material

(Metric tons)

Source	1983	1984	1985	1986	1987
Ores and concentrates:					
Domestic	888,130	989,924	939,257	[1]908,087	[1]972,141
Foreign	39,609	24,200	1,424	W	W
Secondary materials[2]	59,276	169,296	250,138	287,841	276,640
Total	987,015	1,183,420	1,190,819	1,195,928	1,248,781

W Withheld to avoid disclosing company proprietary data; included with "Domestic."
[1]Includes production from foreign ores and concentrates.
[2]Production from secondary sources prior to 1984 excludes data for those plants that were not associated with refineries processing primary materials.

Table 11.—Primary and secondary copper produced by refineries and electrowinning plants in the United States

(Metric tons)

	1983	1984	1985	1986[r]	1987
PRIMARY					
Electrolytic	[r]984,524	[r]1,006,105	[r] [1]966,726	[1]948,623	[1]988,121
Electrowon	[r]101,936	[r]100,180	[r]90,439	125,352	157,986
Fire refined	95,630	58,315	W	W	W
Total	1,182,090	1,164,600	1,057,165	1,073,975	1,146,107
SECONDARY					
Electrolytic	[2]224,761	186,712	264,835	292,686	311,312
Fire refined	[3]176,907	138,237	112,622	113,258	103,426
Total	401,668	324,949	377,457	405,944	414,738
Grand total	1,583,758	1,489,549	1,434,622	1,479,919	1,560,845
Primary domestic materials[4]	1,028,423	1,089,584	1,003,636	[5]1,073,975	[5]1,146,107
Primary foreign materials[4]	153,667	75,016	53,529	W	W
Secondary materials	401,668	324,949	377,457	405,944	414,738
Total	1,583,758	1,489,549	1,434,622	1,479,919	1,560,845

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes fire-refined copper.
[2]Includes some copper fire refined at plants processing primary materials.
[3]Includes some copper electrolytically refined at plants processing secondary materials only.
[4]The separation of refined copper into metal of domestic and foreign origins can only be approximated at this stage of processing.
[5]Includes primary foreign materials.

Table 12.—Copper production by refinery shape at refineries in the United States

(Thousand metric tons)

	1986	1987
Billets	93	W
Cathodes	r1,334	1,431
Ingots and ingot bars	r27	W
Wirebars	16	W
Other forms	10	130
Total	r1,480	1,561

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other forms."

Table 13.—Production, shipments, stocks, and imports of copper sulfate in the United States

(Metric tons)

Year	Production		Shipments[1]	Stocks, Dec. 31	Imports
	Quantity	Copper content			
1983	37,500	9,789	36,614	5,029	2,403
1984	34,859	8,862	37,006	3,564	1,884
1985	32,740	8,265	31,952	4,353	2,958
1986r	34,154	8,616	33,540	4,967	2,683
1987	33,340	8,418	35,338	2,969	4,765

rRevised.
[1]Includes consumption by producing companies.

Table 14.—Byproduct sulfuric acid (100% basis) produced in the United States[1]

(Metric tons)

Plant type	1983	1984	1985	1986	1987
Copper[2]	1,837,827	2,251,312	2,230,257	2,308,804	2,542,602
Lead[3]	319,137	248,474	267,159	122,228	116,311
Zinc[4]	384,529	442,517	430,946	379,803	410,460
Total	2,541,493	2,942,303	2,928,362	2,810,835	3,069,373

[1]Includes acid from foreign materials.
[2]Excludes acid made from pyrite concentrates.
[3]Includes acid processed at molybdenum plants to avoid disclosing company proprietary data.
[4]Excludes acid made from native sulfur.

Table 15.—Copper recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

	1983	1984	1985	1986[r]	1987
KIND OF SCRAP					
New scrap:					
Copper-base	611,890	637,201	621,984	635,495	686,703
Aluminum-base	21,926	21,919	13,330	22,891	25,871
Nickel-base	254	68	328	221	187
Zinc-base	31	31	35	27	12
Total	634,101	659,219	635,677	658,634	712,773
Old scrap:					
Copper-base	431,243	443,585	487,199	461,490	482,890
Aluminum-base	18,015	16,929	15,459	15,859	16,401
Nickel-base	158	102	689	84	65
Zinc-base	62	79	60	36	6
Total	449,478	460,695	503,407	477,469	499,362
Grand total	1,083,579	1,119,914	1,139,084	1,136,103	1,212,135
FORM OF RECOVERY					
As unalloyed copper:					
At electrolytic plants	224,761	186,712	264,835	292,686	311,312
At other plants	194,093	151,477	122,834	121,760	112,712
Total	418,854	338,189	387,669	414,446	424,024
In brass and bronze	625,349	735,154	716,833	671,184	732,440
In alloy iron and steel	1,434	1,705	2,498	1,366	1,254
In aluminum alloys	36,704	43,511	29,423	45,781	50,094
In other alloys	162	307	1,803	359	157
In chemical compounds[1]	1,076	1,048	858	2,967	4,166
Total	664,725	781,725	751,415	721,657	788,111
Grand total	1,083,579	1,119,914	1,139,084	1,136,103	1,212,135

[r]Revised.
[1]Data do not include copper sulfate prior to 1986.

Table 16.—Copper recovered as refined copper and in alloys and other forms from copper-base scrap processed in the United States, by type of operation

(Metric tons)

Type of operation	From new scrap		From old scrap		Total	
	1986[r]	1987	1986[r]	1987	1986[r]	1987
Ingot makers and secondary smelters	17,124	24,013	109,467	122,313	126,591	146,326
Refineries[1]	122,795	131,881	283,149	282,857	405,944	414,738
Brass and wire-rod mills	476,654	512,161	33,940	34,853	510,594	547,014
Foundries and manufacturers	18,611	18,271	32,278	39,078	50,889	57,349
Chemical plants	311	377	2,656	3,789	2,967	4,166
Total	635,495	686,703	461,490	482,890	1,096,985	1,169,593

[r]Revised.
[1]Electrolytically refined and fire-refined scrap based on source of material at smelter level.

Table 17.—Production of secondary copper and copper-alloy products in the United States, by item produced from scrap

(Metric tons)

Item produced from scrap	1986[r]	1987
UNALLOYED COPPER PRODUCTS		
Electrolytically refined copper	292,686	311,312
Fire refined copper	113,258	103,426
Copper powder	7,898	8,709
Copper castings	604	577
Total	414,446	424,024
ALLOYED COPPER PRODUCTS		
Brass and bronze ingots:		
Tin bronzes	23,670	24,221
Leaded red brass and semired brass	99,151	96,615
High-leaded tin bronze	7,223	7,425
Yellow brass	7,641	12,245
Manganese bronze	8,563	7,756
Aluminum bronze	6,818	7,131
Nickel silver	3,215	3,494
Silicon bronze and brass	4,467	4,953
Copper-base hardeners and master alloys	7,067	6,638
Miscellaneous	4,052	9,530
Total	171,867	180,008
Brass mill and wire-rod mill products	628,231	672,987
Brass and bronze castings	34,028	43,957
Brass powder	393	281
Copper in chemical products	2,967	4,166
Grand total	1,251,932	1,325,423

[r]Revised.

Table 18.—Composition of secondary copper-alloy production in the United States

(Metric tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze ingot production:[1]							
1986[r]	137,761	5,525	9,729	18,532	292	28	171,867
1987	143,984	5,804	10,033	19,508	647	32	180,008
Secondary metal content of brass mill products:							
1986[r]	[2]512,222	225	2,687	111,562	1,535	(3)	[2]628,231
1987	[2]545,895	595	2,500	122,722	1,275	--	[2]672,987
Secondary metal content of brass and bronze castings:							
1986	[r]29,032	872	1,511	[r]2,527	25	61	[r]34,028
1987	38,223	1,092	1,857	2,712	18	55	43,957

[r]Revised.
[1]About 94% from scrap and 6% from other than scrap in 1986, and about 96% from scrap and 4% from other than scrap in 1987.
[2]Includes copper recovered from scrap at wire mills to avoid disclosing company proprietary data.
[3]Revised to zero.

Table 19.—Stocks and consumption of purchased copper scrap in the United States in 1987, by class of consumer and type of scrap

(Metric tons, gross weight)

Class of consumer and type of scrap	Stocks, Jan. 1[1]	Net receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
SECONDARY SMELTERS-REFINERS						
No. 1 wire and heavy	4,783	133,584	74,336	58,510	132,866	5,501
No. 2 wire, mixed heavy and light	15,642	329,817	33,490	289,367	322,857	22,602
Composition or soft red brass	2,733	41,848	6,771	35,615	42,386	2,195
Railroad-car boxes	221	1,037	--	1,116	1,116	142
Yellow brass	2,717	35,130	6,909	28,439	35,348	2,499
Cartridge cases	31	214	--	245	245	--
Automobile radiators (unsweated)	3,587	56,828	--	56,822	56,822	3,592
Bronze	1,696	15,909	2,647	13,442	16,089	1,516
Nickel silver and cupronickel	355	3,317	324	2,567	3,291	281
Low brass	100	2,593	1,943	571	2,514	179
Aluminum bronze	77	211	85	124	209	79
Refinery brass	3,168	116,313	45,391	68,539	113,950	5,531
Low-grade scrap and residues	12,506	92,049	62,236	32,002	95,238	9,317
Total	47,616	828,850	234,652	588,380	823,032	53,434
BRASS AND WIRE-ROD MILLS[2]						
No. 1 wire and heavy	12,492	246,300	225,879	20,421	246,300	12,945
No. 2 wire, mixed heavy and light	2,549	56,247	45,940	10,307	56,247	1,737
Yellow brass	6,579	279,721	273,977	5,744	279,721	11,211
Cartridge cases and brass	11,395	78,140	77,438	702	78,140	14,527
Bronze	1,594	4,304	4,304	--	4,304	1,227
Nickel silver and cupronickel	3,305	6,177	5,980	197	6,177	2,009
Low brass	1,335	12,542	12,291	251	12,542	1,721
Total	39,159	683,431	645,809	37,622	683,431	50,477
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy	2,133	31,677	6,577	24,893	31,470	2,340
No. 2 wire, mixed heavy and light	261	4,748	1,076	3,682	4,758	251
Composition or soft red brass	3,533	15,248	7,466	6,514	13,980	4,801
Railroad-car boxes	317	3,634	--	3,740	3,740	211
Yellow brass	838	8,711	6,591	2,309	8,900	649
Cartridge cases	76	--	--	76	76	--
Automobile radiators (unsweated)	468	5,484	27	5,410	5,437	515
Bronze	818	671	18	639	657	832
Nickel silver and cupronickel	17	33	26	23	49	1
Low brass	80	2,336	1,212	1,110	2,322	94
Aluminum bronze	84	724	56	690	756	52
Low-grade scrap and residues	--	28	28	--	28	--
Total[3]	8,625	73,294	23,087	49,086	72,173	9,746
GRAND TOTAL						
No. 1 wire and heavy	19,318	411,561	306,812	103,824	410,636	25,936
No. 2 wire, mixed heavy and light	18,452	390,812	80,506	303,356	383,862	24,590
Composition or soft red brass	6,266	57,096	14,237	42,129	56,366	6,996
Railroad-car boxes	538	4,671	--	4,856	4,856	353
Yellow brass	10,134	323,562	287,477	36,492	323,969	14,359
Cartridge cases	11,502	78,354	77,438	321	78,461	14,527
Automobile radiators (unsweated)	4,055	62,312	27	62,243	62,260	4,107
Bronze	4,108	20,884	6,969	14,782	21,050	2,348
Nickel silver and cupronickel	3,677	9,527	6,830	2,787	9,617	1,509
Low brass	1,515	17,471	15,446	1,932	17,378	2,282
Aluminum bronze	161	935	151	814	965	1,852
Low-grade scrap and residues[4]	15,674	208,390	107,655	101,561	209,216	14,848
Total	95,400	1,585,575	903,548	675,088	1,578,636	113,657

[1]Revised from 1986 closing stocks.

[2]Brass and wire-rod mill stocks include home scrap; purchased scrap consumption is assumed equal to receipts, so lines in "BRASS AND WIRE-ROD MILLS" and "GRAND TOTAL" sections do not balance.

[3]Of the totals shown, chemical plants reported the following: unalloyed copper scrap, 392 tons new and 3,971 tons old.

[4]Includes refinery brass.

Table 20.—Consumption of copper and brass materials in the United States, by item

(Metric tons)

Item	Brass mills	Wire-rod mills	Foundries, chemical plants, miscellaneous users	Secondary smelters-refiners	Total
1986:[r]					
Copper scrap	[1]635,896	W	63,778	800,019	1,499,693
Refined copper[2]	564,875	1,491,945	44,427	1,378	2,102,625
Brass ingot	15,330	--	141,251	--	156,581
Slab zinc	64,883	--	5,434	3,290	73,587
Miscellaneous	--	--	--	1,532	1,532
1987:					
Copper scrap	[1]683,431	W	72,173	823,032	1,578,636
Refined copper[2]	514,528	1,595,598	40,267	1,436	2,151,829
Brass ingot	28,980	--	136,444	--	165,424
Slab zinc	76,454	--	5,158	2,718	84,330
Miscellaneous	--	--	--	710	710

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes consumption of copper scrap at wire-rod mills to avoid disclosing company proprietary data.
[2]Detailed information on consumption of refined copper can be found in table 23.

Table 21.—Apparent consumption of copper in the United States

(Metric tons)

Period	Refined copper production	Total old scrap	Net refined imports	Stock change during period	Apparent consumption
1983	1,182,080	449,478	378,171	-3,000	2,012,739
1984	1,164,600	460,695	353,285	-128,000	2,106,580
1985	1,057,165	503,407	339,788	-244,000	2,144,360
1986	[r]1,073,975	[r]477,469	489,532	-95,000	[r]2,135,976
1987:					
January	93,000	37,281	30,500	-10,600	170,781
February	86,847	39,544	34,739	-11,000	172,130
March	86,618	46,918	51,528	-19,000	204,064
April	79,915	51,308	33,664	-2,000	167,132
May	85,110	40,845	56,181	-5,000	187,136
June	93,968	41,794	66,487	-6,000	208,249
July	90,473	36,292	33,954	28,000	132,719
August	90,167	40,584	42,491	-13,000	186,242
September	102,801	41,199	24,690	-9,000	177,689
October	109,799	42,568	30,811	-30,000	213,178
November	111,764	38,134	28,895	-33,000	211,793
December	115,645	42,601	25,022	-2,000	186,268
Total	1,146,107	499,302	459,962	-112,000	2,217,431

[r]Revised.

Table 22.—Foundries and miscellaneous manufacturers consumption of brass ingot and refined copper and copper scrap in the United States, by geographic division and State

(Metric tons)

Geographic division and State	Tin bronzes	Leaded red brass and semi-red brass	Yellow brass	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot	Refined copper consumed	Copper scrap consumed
1963	24,448	80,741	11,155	5,423	2,511	1,612	5,675	131,565	30,050	60,366
1964	24,660	89,341	6,143	4,907	2,430	1,457	6,426	135,364	34,424	68,396
1965	22,322	94,239	5,833	6,216	3,923	1,788	7,052	141,371	54,390	65,767
1966[r]	29,894	87,990	6,756	5,743	3,024	2,346	5,496	141,251	43,492	60,697
1967:										
New England:										
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	1,618	2,125	404	273	21	438	423	5,301	1,378	483
Middle Atlantic:										
New Jersey, New York, Pennsylvania	6,626	9,562	897	969	77	168	874	19,000	4,481	10,970
East North Central:										
Illinois, Indiana, Michigan, Ohio, Wisconsin	8,061	40,549	1,197	2,858	2,442	687	1,718	58,464	14,191	31,547
West North Central:										
Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota	663	4,734	212	1,074	68	6	252	6,619	2,362	1,883
South Atlantic:										
Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	2,095	10,568	396	308	9	315	216	13,895	7,247	4,598
East and West South Central:										
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	3,192	12,783	228	1,943	96	58	694	19,084	8,480	4,293
Mountain and Pacific:										
Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington	1,987	9,824	1,145	785	35	283	1,023	15,081	865	14,696
Total	24,242	89,734	5,197	7,210	2,763	2,103	5,190	136,444	39,104	67,810

[r]Revised.

Table 23.—Refined copper consumed in the United States, by class of consumer

(Metric tons)

Class of consumer	Cathodes	Wirebars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1986:							
Wire-rod mills	r1,449,758	34,249	W	W	--	r7,938	r1,491,945
Brass mills	r254,928	17,737	r85,707	80,033	126,452	18	r864,875
Chemical plants	W	--	--	--	--	935	935
Ingot makers	r1,068	--	W	W	--	r312	r1,378
Foundries	2,855	533	15,209	W	1,495	r530	r20,622
Miscellaneous[1]	9,124	W	4,984	1,616	W	r7,146	r22,870
Total[r]	1,717,731	52,519	105,900	81,649	127,947	16,879	2,102,625
1987:							
Wire-rod mills	1,564,883	W	W	W	--	10,715	1,595,598
Brass mills	250,167	13,845	96,948	66,920	86,526	132	514,528
Chemical plants	W	--	--	--	--	1,163	1,163
Ingot makers	W	--	W	W	W	1,436	1,436
Foundries	2,822	690	11,355	W	W	1,845	16,612
Miscellaneous[1]	11,286	W	4,988	1,493	W	4,715	22,492
Total	1,849,158	14,435	113,291	68,413	86,526	20,006	2,151,829

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and other manufacturers.

Table 24.—Stocks of copper in the United States, December 31

(Thousand metric tons)

Period	Blister and materials in process of refining[1]	Refined copper					
		Electrolytic refiners	Wire rod mills	Brass mills	Other[2]	New York Commodity Exchange	Total
1982	174	154	116	26	25	371	692
1984	245	125	134	27	27	251	564
1985	146	66	100	20	25	109	320
1986	135	36	66	14	25	84	225
1987:							
January	121	32	43	17	24	98	216
February	114	28	32	21	24	99	204
March	118	24	32	15	24	90	185
April	95	32	31	16	24	80	183
May	123	28	30	21	24	65	178
June	114	27	33	19	24	69	172
July	127	50	44	19	24	62	200
August	123	40	36	20	24	67	187
September	130	36	21	16	24	81	178
October	133	31	17	16	24	60	148
November	129	27	17	16	24	31	115
December	130	29	28	15	24	17	113

[1]Includes copper in transit from smelters in the United States to refineries therein.
[2]Includes secondary smelters, chemical plants, foundries, and miscellaneous plants; includes 20,000 tons in the National Defense Stockpile.

Table 25.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York, by type

(Cents per pound)

Year and month	Scrap		Ingot	
	No. 2 heavy copper	No. 1 composition (red brass)	No. 115 brass (85-5-5-5)	Yellow brass (405)
1986:				
January	r38.23	39.50	81.50	70.75
February	39.50	39.50	81.50	70.75
March	39.50	39.50	81.50	70.75
April	39.50	39.50	81.50	70.75
May	39.50	39.50	81.50	70.75
June	39.50	39.50	81.50	70.75
July	39.50	39.50	81.50	70.75
August	r37.79	36.98	81.50	70.75
September	37.50	36.50	81.50	70.75
October	37.50	36.50	81.50	70.75
November	37.50	36.50	81.50	70.75
December	r35.50	36.50	81.50	70.75
Average	r38.42	38.29	81.50	70.75
1987:				
January	37.50	46.50	81.50	70.75
February	37.50	46.50	81.50	70.75
March	37.89	47.08	81.50	70.75
April	39.50	49.50	81.50	70.75
May	41.18	50.34	81.50	70.75
June	42.50	51.50	81.50	70.75
July	44.56	53.56	85.00	73.25
August	49.02	58.02	85.00	73.25
September	49.50	58.50	85.00	73.25
October	55.40	58.82	88.00	76.25
November	56.50	66.50	93.00	79.25
December	65.15	75.15	100.50	84.25
Average	46.35	55.16	85.46	73.67

rRevised.

Source: American Metal Market.

Table 26.—Average monthly prices for refined copper in the United States and on the London Metal Exchange

(Cents per pound)

Month	1986					1987				
	U.S. producers delivered price		COMEX first position	LME cash price[1]		U.S. producers delivered price		COMEX first position	LME cash price[1]	
	Cathode[2]	Wirebar[3]		Cathode	High grade[4]	Cathode[2]	Wirebar[3]		Cathode	High grade[4]
January	69.88	69.88	65.29	63.28	64.31	64.99	64.99	60.76	59.27	61.04
February	68.25	68.25	63.86	62.96	63.73	65.53	65.53	61.73	60.46	62.57
March	70.14	70.14	66.02	65.26	65.52	68.07	68.07	63.57	62.36	66.45
April	68.80	68.80	63.80	64.93	65.05	67.13	67.13	62.37	63.86	68.29
May	67.09	67.09	62.72	63.29	64.24	70.99	70.99	66.47	66.27	68.94
June	67.47	67.47	62.57	63.20	64.07	74.35	74.35	69.89	69.85	71.27
July	63.82	63.82	58.94	58.44	60.96	80.42	80.42	76.19	76.68	76.83
August	62.37	62.37	57.59	57.52	59.08	82.18	82.18	77.63	79.51	79.63
September	64.84	64.84	60.71	59.43	61.08	85.61	85.61	80.99	81.86	82.11
October	63.46	63.46	59.19	58.27	59.71	88.85	88.85	83.04	87.63	89.16
November	62.86	62.86	58.93	57.71	59.10	108.53	108.53	103.92	109.67	114.35
December	63.64	63.64	60.17	58.68	60.56	133.32	133.32	127.49	123.41	129.96
Average	66.05	66.05	61.65	61.08	62.28	82.50	82.50	77.84	78.40	80.88

[1]Based on average monthly rates of exchange.
[2]Listed as "U.S. producer cathode."
[3]Listed as "U.S. producer delivered."
[4]Includes both cathode and wirebar.

Source: Metals Week.

Table 27.—U.S. exports of copper, by country

Country	Ore and concentrate (copper content)		Ashes and residues[1] (copper content)		Refined		Unalloyed copper scrap		Blister and precipitates	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	174,348	$187,826	3,826	$10,671	12,452	$18,444	136,422	$123,138	15,963	$17,434
1987:										
Australia	--	--	--	--	--	--	142	89	345	407
Belgium-Luxembourg	--	--	2,397	4,688	--	--	1,955	2,057	--	--
Brazil	--	--	--	--	68	95	3,017	3,621	--	--
Canada	1,826	5,244	1,898	3,314	1,670	2,399	11,134	17,288	836	963
China	2,470	2,094	--	--	--	--	191	79	--	--
Dominican Republic	--	--	--	--	22	41	--	--	16	8
Finland	7,228	7,755	--	--	--	--	88	18	1	2
France	--	--	34	61	440	902	--	--	16	32
Germany, Federal Republic of	886	461	604	3,872	433	826	4,331	4,242	--	--
Hong Kong	--	--	--	--	402	871	3,317	1,919	711	1,484
India	101	89	312	184	--	--	494	375	20	18
Israel	--	--	--	--	--	--	--	--	25	43
Italy	--	--	--	--	194	431	6,141	5,727	3	5
Japan	99,562	122,124	157	440	2,479	6,033	15,550	20,396	4,269	1,709
Korea, Republic of	5,154	9,324	--	--	1,781	4,221	9,662	12,279	4,647	5,440
Kuwait	--	--	7	24	--	--	--	--	--	--
Mexico	3	3	--	--	510	680	12,277	17,961	275	434
Netherlands	--	--	--	--	20	42	369	348	--	--
Philippines	--	--	1	2	--	--	948	252	89	91
Saudi Arabia	--	--	--	--	--	--	--	--	(*)	8
Singapore	--	--	--	--	2	3	1,145	1,050	102	201
Spain	4	7	--	--	--	--	8,053	3,473	4	12
Sweden	--	--	--	--	--	--	2	2	--	--
Switzerland	--	--	2	2	38	66	1	17	--	--
Taiwan	3,776	5,033	530	288	207	297	28,713	12,208	473	991
Trinidad and Tobago	18	18	--	--	11	16	44	5	--	--
United Arab Emirates	--	--	17	29	--	--	--	--	--	--
United Kingdom	--	--	40	250	908	1,987	746	1,245	14	21
Venezuela	--	--	--	--	--	--	196	238	65	85
Yugoslavia	3,731	4,858	--	--	--	--	--	--	--	--
Other	--	--	--	--	12	18	19	3	434	509
Total	124,749	157,010	5,999	13,154	9,197	18,928	108,535	104,901	12,339	12,463

Country	Pipes and tubing		Plates and sheets		Wire and cable, bare		Wire and cable, insulated		Other copper manufactures[3]	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	5,343	$15,605	641	$2,151	7,393	$32,482	60,816	$358,677	9,583	$20,799
1987:										
Australia	1	5	(2)	4	31	239	1,044	8,883	1	4
Bahamas	(2)	2	--	--	22	61	279	1,000	--	--
Belgium-Luxembourg	18	57	(2)	3	13	80	135	3,550	1	10
Brazil	295	922	3	17	142	230	378	4,378	(2)	2
Canada	1,631	4,349	216	944	1,352	6,199	35,091	90,231	1,560	4,706
China	203	373	2	11	397	3,149	684	4,739	--	--
Dominican Republic	81	128	(2)	2	652	5,621	423	1,862	4	15
Ecuador	36	96	(2)	3	--	--	115	481	--	--
Egypt	76	204	--	--	3	15	5,437	17,310	5	15
France	16	57	1	15	10	76	1,400	37,933	1	6
Germany, Federal Republic of	1	17	1	5	54	445	3,030	27,785	1	11
Hong Kong	50	155	2	21	39	517	422	3,439	3	10
India	(2)	2	--	--	31	232	95	1,660	9	53
Israel	70	211	5	27	23	210	212	2,914	--	--
Italy	16	41	1	4	65	724	335	5,642	--	--
Jamaica	23	88	--	--	58	189	169	687	1	4
Japan	81	278	19	80	122	638	654	17,339	11	68
Korea, Republic of	1	6	1	8	36	269	1,273	10,226	18	46
Kuwait	147	378	--	--	2	20	58	228	--	--
Mexico	374	1,133	150	688	6,286	19,592	22,256	126,498	1,040	2,683
Netherlands	319	854	--	--	35	252	470	6,659	--	--
Philippines	21	60	40	641	41	136	303	1,369	3	10
Saudi Arabia	515	1,336	--	--	32	132	1,395	5,062	1	10
Singapore	81	425	1	10	31	158	912	8,522	7	32
Spain	254	643	1	10	14	82	171	4,503	(2)	9
Sweden	32	87	44	55	3	20	113	4,213	2	16
Switzerland	7	21	--	--	13	227	281	2,668	2	9
Taiwan	105	297	22	72	56	176	551	6,592	16	78
Trinidad and Tobago	5	13	--	--	39	109	283	728	--	--
United Arab Emirates	184	444	--	--	7	26	179	1,934	--	--
United Kingdom	354	891	6	31	100	836	3,705	48,113	2	6
Venezuela	518	1,876	12	121	30	107	213	1,475	2	8
Yugoslavia	7	20	--	--	--	--	7	125	(2)	2
Other	1,029	2,781	12	55	455	2,102	6,087	31,818	1,033	1,698
Total	6,551	18,250	539	2,827	10,194	42,869	88,240	490,556	3,723	9,511

[1]Includes matte.
[2]Less than 1/2 unit.
[3]Excludes copper wire cloth.

Source: Bureau of the Census.

Table 28.—U.S. exports of copper scrap, by country

Country	Unalloyed copper scrap				Copper-alloy scrap			
	1986		1987		1986		1987	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium-Luxembourg	3,221	$4,027	1,955	$2,057	5,645	$4,453	7,276	$6,674
Brazil	3,967	3,855	3,017	3,621	3,994	4,053	6,384	7,055
Canada	13,746	21,664	11,134	17,288	20,970	33,410	21,156	37,095
China	336	179	191	79	109	131	180	404
France	175	199	---	---	114	153	96	403
Germany, Federal Republic of	8,514	10,560	4,331	4,242	5,050	5,722	7,723	10,127
Hong Kong	5,726	2,242	3,817	1,919	752	445	521	363
India	717	631	494	375	16,566	16,801	11,866	9,364
Italy	12,326	12,421	6,141	5,727	19,606	17,927	6,510	5,287
Japan	12,551	15,732	15,550	20,396	25,712	28,096	24,040	34,346
Korea, Republic of	12,368	13,868	9,662	12,279	14,463	15,842	26,091	31,786
Mexico	5,885	5,919	12,277	17,961	923	1,170	5,723	8,179
Netherlands	1,713	1,691	369	348	1,497	1,353	803	896
Philippines	263	110	948	252	23	87	115	39
Singapore	684	466	1,145	1,059	305	221	232	174
Spain	5,615	3,781	8,053	3,473	7,799	3,507	6,269	2,780
Sweden	33	76	2	2	2,346	3,130	1,599	2,585
Switzerland	104	109	1	17	278	228	163	110
Taiwan	46,898	23,835	28,713	12,208	22,027	19,333	54,657	34,097
Trinidad and Tobago	---	---	44	5	---	---	704	702
United Kingdom	1,485	1,675	746	1,245	4,221	3,503	2,698	3,544
Venezuela	---	---	196	238	---	---	127	611
Other	95	101	249	110	571	1,336	346	317
Total[1]	136,422	123,138	108,535	104,901	152,971	160,921	185,279	196,938

[1]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 29.—U.S. imports for consumption of unmanufactured copper (copper content), by country

Country	Ore and concentrate		Matte		Blister and anode		Refined		Unalloyed scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1986	4,232	$2,593	702	$573	34,545	$60,236	501,984	$677,010	27,216	$31,646	568,679	$772,058
1987:												
Belgium-Luxembourg	--	--	--	--	--	--	637	240	--	--	637	240
Canada	2,338	2,009	651	372	14	26	298,158	338,324	25,675	35,804	326,836	376,535
Chile	--	--	--	--	7,329	9,987	125,917	196,851	--	--	133,256	206,838
China	--	--	--	--	--	--	150	261	--	--	150	261
Costa Rica	--	--	--	--	--	--	--	--	194	247	194	247
Dominican Republic	--	--	--	--	--	--	--	--	537	722	537	722
Germany, Federal Republic of	--	--	--	--	87	225	23,961	42,434	--	--	24,048	42,659
Guatemala	--	--	--	--	--	--	--	--	85	80	85	80
Japan	--	--	--	--	1,986	3,221	599	819	--	--	2,585	4,040
Korea, Republic of	--	--	--	--	--	--	--	--	112	138	112	138
Mexico	1	4	6,127	8,759	6,762	16,103	553	541	5,344	6,541	18,787	31,948
Netherlands	--	--	--	--	--	--	6,390	12,104	--	--	6,390	12,104
Netherlands Antilles	--	--	--	--	--	--	--	--	86	94	86	94
Norway	--	--	--	--	--	--	186	343	--	--	186	343
Panama	--	--	--	--	--	--	--	--	391	530	391	530
Peru	--	--	91	208	2,050	4,918	34,387	44,875	50	63	37,178	50,064
El Salvador	--	--	--	--	--	--	--	--	151	161	151	161
South Africa, Republic of	--	--	--	--	5,246	7,496	4,580	6,220	--	--	9,826	13,716
Sweden	--	--	--	--	--	--	15,230	21,460	--	--	15,230	21,460
Taiwan	--	--	--	--	--	--	272	344	23	50	295	394
Trinidad and Tobago	--	--	--	--	--	--	--	--	84	99	84	99
Yugoslavia	--	--	--	--	--	--	4,199	5,556	--	--	4,199	5,556
Zaire	--	--	--	--	--	--	23,992	33,579	--	--	23,992	33,579
Zambia	--	--	--	--	--	--	19,805	30,416	--	--	19,805	30,416
Other	--	--	--	--	--	--	143	280	391	592	534	872
Total	2,339	2,013	6,869	9,339	24,084	41,976	469,159	734,647	33,123	45,121	535,574	833,096

Source: Bureau of the Census.

Table 30.—U.S. imports for consumption of copper scrap, by country

Country	Unalloyed copper scrap		Copper-alloy scrap		
	Quantity (metric tons)	Value (thousands)	Gross weight (metric tons)	Copper content (metric tons)	Value (thousands)
1986	27,216	$31,646	39,017	28,844	$40,250
1987:					
Bahamas	21	28	34	24	24
Barbados	61	71	37	28	28
Belgium-Luxembourg	--	--	39	21	64
Canada	25,675	35,804	29,630	23,059	35,946
Chile	--	--	105	85	111
Costa Rica	194	247	36	26	28
Dominican Republic	537	722	421	333	402
France	22	121	22	23	64
Germany, Federal Republic of	--	--	275	176	435
Guatemala	85	80	74	55	62
Honduras	37	30	2	2	1
Italy	57	83	148	121	95
Jamaica	56	56	123	111	125
Japan	--	--	52	51	89
Korea, Republic of	112	138	139	136	306
Malaysia	27	33	49	48	111
Mexico	5,344	6,541	10,496	6,791	10,760
Netherlands	--	--	37	21	44
Netherlands Antilles	86	94	233	175	168
Panama	391	530	711	419	490
Peru	50	63	571	459	764
El Salvador	151	161	--	--	--
Singapore	72	76	103	81	112
Sweden	--	--	71	51	100
Switzerland	--	--	46	45	82
Taiwan	23	50	33	46	94
Trinidad and Tobago	84	99	141	109	109
United Kingdom	22	78	291	183	575
Venezuela	--	--	189	131	396
Other	16	16	75	63	110
Total	33,123	45,121	44,183	32,874	51,696

Source: Bureau of the Census; figures adjusted by Bureau of Mines.

Table 31.—Copper: World mine production,[1] by country

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Albania[e]	14.9	16.1	16.2	17.6	17.6
Algeria	.1	.1	--	--	--
Argentina	.3	.2	.4	.3	.3
Australia	261.5	r235.7	259.8	245.4	223.0
Bolivia	2.0	1.6	1.7	.3	(2)
Botswana[3]	r20.3	21.5	21.7	19.0	e19.0
Brazil	32.1	35.2	41.0	36.2	37.8
Bulgaria[e]	80.0	80.0	80.0	80.0	80.0
Burma	4.2	12.0	16.7	11.4	15.0
Canada[3]	653.0	r721.8	738.6	698.5	767.3
Chile[3]	r1,255.4	r1,307.5	1,359.8	1,299.4	1,417.8
China[e]	175.0	180.0	185.0	185.0	300.0
Colombia	.2	.2	--	--	--
Congo (Brazzaville)	(2)	NA	.5	NA	NA
Cuba	2.7	2.7	3.1	e3.3	3.0
Cyprus[7]	2.1	2.3	2.1	1.2	1.0
Czechoslovakia	9.8	10.0	e10.3	e10.0	10.0
Ecuador	(2)	.2	.1	.1	.1
Finland	39.3	31.3	28.0	25.9	e20.4
France	.1	.1	.2	.3	e.3
German Democratic Republic[e]	12.0	12.0	12.0	10.0	9.0
Germany, Federal Republic of[3]	1.2	1.0	.9	.8	e1.5
Guatemala	--	--	4.5	e4.2	4.2
Honduras	e.6	.8	5.1	e5.0	5.0
India	37.8	44.1	45.9	48.1	e54.8
Indonesia	78.6	82.5	88.7	95.8	102.0
Iran[e]	57.6	43.3	50.0	48.0	48.0

See footnotes at end of table.

Table 31.—Copper: World mine production,[1] by country —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Israel	3.5	e2.9	--	--	--
Italy	1.5	.9	.1	--	--
Japan	46.0	43.3	43.2	34.9	e22.0
Korea, North[e]	15.0	15.0	15.0	15.0	15.0
Korea, Republic of	.4	.3	.3	e.2	e.2
Malaysia	29.0	28.9	30.5	28.3	e30.1
Mexico	196.0	303.5	276.1	e285.0	300.0
Mongolia[e]	104.0	118.0	128.0	r136.0	136.0
Morocco	25.4	22.1	22.0	20.2	e16.6
Mozambique	.2	.3	.1	.3	.2
Namibia	50.4	47.4	48.0	49.6	50.0
Nepal	(3)	(3)	(3)	(3)	(3)
Norway	22.6	25.0	19.0	21.9	22.0
Oman	11.3	16.2	17.7	18.0	18.0
Papua New Guinea	201.9	r164.4	175.0	178.2	e217.7
Peru[e]	318.8	353.9	391.3	397.4	392.3
Philippines	271.4	233.4	222.2	222.6	e215.0
Poland	402.2	431.0	431.3	434.0	437.0
Portugal[e]	.3	.4	.3	.2	e.1
Romania[e 5]	27.0	25.0	26.0	27.0	26.0
South Africa, Republic of[e]	205.0	198.2	195.4	184.2	e213.0
Spain	50.0	63.1	55.5	46.9	e15.0
Sweden	74.6	87.0	91.8	87.4	e90.3
Turkey[e]	24.9	27.1	33.0	e33.0	35.0
U.S.S.R.[e 5]	570.0	590.0	r600.0	620.0	630.0
United Kingdom	.7	.7	.6	.6	e.8
United States:[5]					
By concentration or leaching	r936.1	r1,002.4	1,015.4	1,021.9	e1,097.9
Leaching (electrowon)	r102.0	r100.2	90.4	125.4	e158.0
Yugoslavia[e]	r129.5	137.6	r e141.3	r e144.9	144.3
Zaire	536.5	562.0	557.9	e563.0	564.0
Zambia:[10]					
By concentration or leaching	406.6	406.8	354.7	322.6	330.0
Leaching (electrowon)	134.4	125.9	102.9	139.3	140.0
Zimbabwe	21.6	24.0	21.6	21.4	21.0
Total	r7,659.1	r7,909.1	8,079.3	8,125.2	8,474.8

e Estimated. p Preliminary. r Revised. NA Not available.

[1] Data represent copper content by analysis of concentrates produced except where otherwise specified. Table includes data available through July 8, 1988.

[2] Less than 50 tons.

[3] Copper content of matte produced.

[4] Reported figure.

[5] Recoverable content.

[6] Recoverable copper content by analysis of concentrates for export plus nonduplicative total of copper content of all metal and metal products produced indigenously from domestic ores and concentrates. Includes leach production for electrowinning.

[7] Includes copper content of cupriferous pyrite.

[8] Data are for fiscal year beginning Mar. 21 of that stated.

[9] Copper content by analysis of ore mined.

[10] Data are for fiscal year beginning Apr. 1 of that stated.

Table 32.—Copper: World smelter production,[1] by country

(Thousand metric tons)

Country[2] and metal origin	1983	1984	1985	1986[p]	1987[e]
Albania, primary	11.0	12.6	e12.6	e13.7	14.0
Australia:					
Primary	173.6	179.8	167.7	169.6	177.0
Secondary	8.2	r8.1	e8.0	e8.0	8.5
Total	181.8	r187.9	e175.7	r e177.6	185.5
Austria, secondary	r24.3	r24.6	25.9	25.5	26.0
Belgium:[e]					
Primary	2.8	.5	.9	2.0	1.5
Secondary	70.5	75.5	114.2	106.0	60.7
Total	73.3	76.0	115.1	108.0	62.2
Brazil, primary	63.1	61.3	93.9	116.0	139.9
Bulgaria:[e]					
Primary	57.0	57.0	87.0	87.0	87.0
Secondary	3.0	3.0	3.0	3.0	4.0
Total	60.0	60.0	90.0	90.0	91.0
Canada:					
Primary	499.7	504.3	493.3	472.7	474.0
Secondary[3]	11.0	11.0	17.0	12.0	14.0
Total[e]	510.7	515.3	510.3	r484.7	488.0
Chile, primary[3]	1,058.9	1,098.3	1,088.5	1,124.1	1,103.7
China, primary[e]	195.0	210.0	225.0	225.0	300.0
Czechoslovakia:					
Primary	10.0	10.0	10.2	e10.0	10.0
Secondary	2.4	2.4	e2.4	e2.4	2.4
Total[e]	12.4	12.4	12.6	12.4	12.4
Finland:					
Primary	74.5	71.2	e71.0	e70.0	68.9
Secondary	12.6	12.1	e12.0	e12.0	12.0
Total	87.1	83.3	e83.0	e82.0	80.9
France, secondary	7.2	6.8	7.0	6.1	6.0
German Democratic Republic, primary[e]	17.0	14.0	14.0	12.0	12.0
Germany, Federal Republic of:					
Primary	159.1	148.8	152.4	161.9	161.0
Secondary	94.5	76.7	94.6	76.7	76.5
Total	253.6	225.5	247.0	238.6	237.5
Hungary, secondary[e]	.1	.1	.1	.1	.1
India, primary	35.5	49.5	32.5	39.1	37.1
Iran, primary[e]	r8.5	r47.9	r60.0	60.0	60.0
Japan:					
Primary	944.6	821.1	802.3	827.7	4871.0
Secondary	117.3	107.9	130.3	134.4	497.7
Total	1,061.9	929.0	932.6	962.1	4968.7
Korea, North:[e]					
Primary	15.0	15.0	15.0	15.0	15.0
Secondary	3.0	3.0	3.0	3.0	3.0
Total	18.0	18.0	18.0	18.0	18.0
Korea, Republic of, primary and secondary	124.0	100.2	106.9	165.0	4157.9
Mexico, primary	r59.5	r70.3	68.2	74.7	4101.4
Namibia, primary	54.2	46.4	43.3	45.7	45.7
Norway, primary	25.7	36.8	38.2	35.2	429.7
Oman, primary	7.6	21.3	18.8	19.6	19.6
Peru, primary	258.3	298.8	326.6	286.2	4286.6
Philippines, primary	57.6	109.2	133.8	124.3	4124.7
Poland:[3]					
Primary	349.0	360.0	370.0	375.0	375.0
Secondary	13.0	15.0	20.0	25.0	25.0
Total	362.0	375.0	390.0	400.0	400.0

See footnotes at end of table.

Table 32.—Copper: World smelter production,[1] by country —Continued

(Thousand metric tons)

Country[2] and metal origin	1983	1984	1985	1986[p]	1987[e]
Portugal:[e]					
Primary	3.2	2.5	2.6	3.0	2.0
Secondary	3.0	1.0	2.0	3.0	2.0
Total	6.2	3.5	4.6	6.0	4.0
Romania:[e]					
Primary	34.0	32.0	32.0	32.0	30.0
Secondary	6.0	6.0	6.0	7.0	8.0
Total	40.0	38.0	38.0	39.0	38.0
South Africa, Republic of, primary	192.3	178.7	191.7	[r e]192.0	192.0
Spain:					
Primary	100.0	97.0	88.0	[r e]95.0	96.7
Secondary	18.0	30.0	40.0	[e]40.0	42.0
Total	118.0	127.0	128.0	[r e]135.0	138.7
Sweden:					
Primary	78.8	79.8	74.7	[r e]82.5	84.0
Secondary	23.1	22.9	26.0	[e]20.0	21.6
Total	101.9	102.7	100.7	[r e]102.5	105.6
Taiwan, primary	[r]38.0	48.4	46.7	50.4	47.0
Turkey:					
Primary	18.8	31.8	33.5	35.2	34.8
Secondary	.3	.2	.4	.3	.2
Total	19.1	32.0	33.9	35.5	35.0
U.S.S.R.:[e]					
Primary	700.0	735.0	750.0	770.0	780.0
Secondary	139.0	141.0	143.0	145.0	147.0
Total	839.0	876.0	893.0	915.0	927.0
United States:					
Primary[3]	927.7	1,014.1	940.7	908.1	[4]972.1
Secondary	59.3	169.3	250.1	287.8	[4]276.6
Total	987.0	1,183.4	1,190.8	1,195.9	[4]1,248.7
Yugoslavia, primary	86.8	84.7	[r e]137.1	[r e]127.2	126.0
Zaire, primary:					
Electrowon	304.1	309.1	313.9	319.2	320.0
Other	175.0	171.5	172.9	178.9	180.0
Total	479.1	480.6	486.8	498.1	500.0
Zambia, primary	562.7	531.8	522.6	452.9	474.0
Zimbabwe, primary	21.6	22.7	20.4	20.4	20.4
Grand total	[r]8,120.0	[r]8,391.0	8,663.9	8,714.7	8,865.0
Of which:					
Primary:					
Electrowon	304.1	309.1	313.9	319.2	320.0
Other	[r]7,076.1	[r]7,265.1	7,338.1	7,313.2	[r]7,553.8
Secondary	[r]615.8	[r]716.6	905.0	917.3	833.3
Undifferentiated	124.0	100.0	106.9	165.0	167.9

[e]Estimated. [p]Preliminary. [r]Revised.

[1]This table includes total production of copper metal at the unrefined stage, including low-grade cathode produced by electrowinning methods. The smelter feed may be derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through July 8, 1988.

[2]Argentina presumably produces some smelter copper utilizing its own small mine output together with domestically produced cement copper and possibly using other raw materials including scrap, but the levels of such output cannot be reliably estimated.

[3]Data include electrowon production; estimated to be 35,000 to 45,000 tons per year that is fire refined and cast into wirebars; detailed data are not available.

[4]Reported figure.

[5]Figures for U.S. primary smelter production may include a small amount of copper derived from precipitates shipped directly to the smelter for further processing; production derived from electrowinning and fire refining is not included. Copper content of precipitates shipped directly to smelter are as follows, in metric tons: 1983—89,274; 1984—80,845; 1985—82,948; 1986—79,031; and 1987—69,376. Production from scrap prior to 1984 excludes data from secondary smelters processing only scrap.

Table 33.—Copper: World refinery production,[1] by country

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[p]
Albania, primary[e]	10.5	11.5	11.5	11.7	12.0
Australia:					
Primary	168.5	171.2	163.8	164.0	185.0
Secondary	34.1	26.0	30.5	20.4	25.8
Total[3]	202.6	197.2	194.3	184.3	210.8
Austria:					
Primary	8.8	9.6	8.2	7.1	7.0
Secondary	33.1	34.3	35.0	32.6	42.0
Total[3]	41.9	43.9	43.2	39.6	49.0
Belgium:					
Primary	360.3	351.7	340.5	r e311.7	307.5
Secondary	71.0	76.0	115.0	r e100.9	100.0
Total	431.3	427.7	455.5	r e412.6	407.5
Brazil:					
Primary	63.1	61.3	93.9	116.0	139.9
Secondary	39.3	36.0	49.0	50.0	50.0
Total	102.4	97.3	142.9	166.0	189.9
Bulgaria, primary and secondary[e]	62.0	62.0	93.0	95.0	95.0
Canada:					
Primary	464.3	504.3	499.6	493.4	491.2
Secondary[2]	33.0	35.0	34.0	33.0	34.0
Total[3]	497.3	539.3	533.6	r598.4	525.2
Chile, primary	834.2	879.7	884.3	942.5	945.0
China, primary and secondary[e]	310.0	310.0	400.0	400.0	400.0
Czechoslovakia, primary and secondary	25.7	26.1	e26.5	e26.5	26.5
Egypt, secondary	2.4	2.6	e2.6	e2.7	3.0
Finland:					
Primary	45.4	47.3	e46.5	r e52.2	47.5
Secondary[e]	10.0	10.0	12.0	12.0	12.0
Total	55.4	57.3	e58.5	r e64.2	59.5
France:					
Primary[e]	7.8	15.0	13.7	r15.1	13.3
Secondary	37.3	25.9	30.0	26.8	26.0
Total	45.1	40.9	43.7	r e41.9	39.3
German Democratic Republic, primary and secondary[e]	68.0	65.0	63.0	63.0	58.0
Germany, Federal Republic of:					
Primary	r212.5	r207.1	210.1	238.0	e232.8
Secondary	r207.8	r171.7	204.3	183.9	e167.0
Total[3]	r420.3	r378.8	414.4	421.9	e399.8
Hungary, primary and secondary[e]	12.5	12.8	12.8	12.8	12.5
India, primary:					
Electrolytic	28.4	32.6	28.0	37.9	32.2
Fire refined[e]	1.0	1.0	1.0	1.0	1.0
Total[e]	29.4	33.6	29.0	r38.9	33.2
Iran, primary[4]	10.0	5.0	12.0	12.0	12.0
Italy, secondary	31.2	50.3	64.3	65.4	65.1
Japan:					
Primary	944.6	821.1	802.3	827.7	e871.0
Secondary	147.4	114.1	133.6	115.4	e109.4
Total[3]	1,091.9	935.2	936.0	943.0	e980.3

See footnotes at end of table.

Table 33.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
Korea, North, primary and secondary[e]	22.0	22.0	22.0	22.0	22.0
Korea, Republic of:					
Primary	123.3	129.1	140.1	157.8	[p]156.3
Secondary[e]	11.5	7.9	11.5	[r]7.2	8.7
Total[p]	134.8	137.0	151.6	[r]165.0	165.0
Mexico:					
Primary:					
Electrowon	7.5	9.2	8.0	8.0	10.0
Other	61.0	69.0	101.5	66.5	96.4
Secondary[e]	15.0	[r p]13.9	14.0	15.0	15.0
Total[e p]	[r]83.5	[p]92.2	[r]122.6	[p]89.5	120.4
Norway, primary[e]	22.7	30.3	31.1	30.5	29.4
Oman, primary	3.9	[r]15.2	14.3	18.0	18.0
Peru, primary:					
Electrowon	33.0	31.5	27.4	27.5	27.5
Other	161.4	188.6	203.0	197.7	190.9
Total[p]	194.4	220.0	230.5	225.3	218.4
Philippines, primary	38.8	99.2	130.2	134.5	[p]132.1
Poland, primary[e]	360.0	372.3	387.0	388.0	[p]390.0
Portugal, primary	[e]4.6	5.2	4.5	5.3	4.8
Romania:[e]					
Primary	35.0	33.0	33.0	32.0	30.0
Secondary	12.0	12.0	12.0	11.0	12.0
Total	47.0	45.0	45.0	43.0	42.0
South Africa, Republic of, primary[e]	157.7	155.7	164.3	158.6	155.0
Spain:					
Primary	137.6	117.4	101.7	[e]113.2	109.8
Secondary	21.0	39.0	50.0	[e]45.0	50.0
Total	158.6	156.4	151.7	[e]158.2	159.8
Sweden:					
Primary	50.1	53.5	[e]52.0	[e]60.0	55.0
Secondary	13.2	10.4	12.7	[e]20.0	15.0
Total[p]	63.4	63.9	64.7	[e]80.0	70.0
Taiwan:					
Primary[e]	30.0	40.4	46.7	[r]50.4	[p]47.0
Secondary[e]	8.0	8.0	8.0	8.0	10.0
Total	38.0	48.4	54.7	58.4	57.0
Turkey, primary	31.8	39.0	[e]30.0	[e]35.0	35.0
U.S.S.R.:[e]					
Primary	776.0	[p]790.0	810.0	[p]830.0	840.0
Secondary	139.0	141.0	143.0	145.0	147.0
Total	915.0	[p]931.0	953.0	[p]975.0	987.0
United Kingdom:					
Primary	67.5	69.5	63.9	62.4	62.0
Secondary	76.8	67.4	61.6	63.2	63.0
Total[p]	144.4	136.9	125.4	125.6	125.0

See footnotes at end of table.

Table 33.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

Country	1983	1984	1985	1986[p]	1987[e]
United States:					
Primary:					
Electrowon	r101.9	r108.2	99.4	125.4	r158.0
Other	r1,080.2	r1,064.4	968.7	948.6	r998.1
Secondary	401.7	324.9	377.5	405.9	r414.7
Total	r1,583.8	r1,489.5	1,434.6	1,479.9	r1,560.8
Yugoslavia:					
Primary	82.9	80.3	r e80.0	r e81.0	80.5
Secondary	40.8	r47.4	r e55.4	r e59.4	58.4
Total[2]	123.7	127.6	135.4	140.4	r138.9
Zaire, primary	227.2	224.8	221.4	219.0	220.0
Zambia, primary:[3]					
Electrowon	r194.4	r125.9	103.9	139.2	r140.0
Other	r406.6	r406.8	354.7	322.6	r323.0
Total	r541.0	r532.7	458.6	461.9	r463.0
Zimbabwe, primary	23.6	22.7	29.4	30.4	30.0
Grand total[2]	r9,291.7	r9,116.1	9,375.1	9,503.1	9,647.1
Of which:					
Primary[4]	r7,315.9	r7,284.5	7,392.0	7,461.0	7,605.2
Secondary[5]	r1,985.6	r1,238.8	1,455.9	1,422.8	1,427.9
Primary and secondary, undifferentiated	500.2	497.9	617.3	615.3	614.0

[e]Estimated. [p]Preliminary. [r]Revised.

[1]This table includes total production of refined copper, whether produced by pyrometallurgical or electrolytic refining methods and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. To the extent possible, primary and secondary output of each country is shown separately. In most cases, total refinery production is officially reported, and in some, the distribution between primary and secondary has been estimated. Table includes data available through July 8, 1988.

[2]Data may not add to totals shown because of independent rounding.

[3]Reported figure.

[4]Data are for fiscal year beginning Mar. 21 of that stated.

[5]May include small quantities of secondary.

[6]Although only primary production is reported, an unknown but small additional output of secondary refined copper may have been produced.

[7]Data are for fiscal year beginning Apr. 1 of that stated.

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